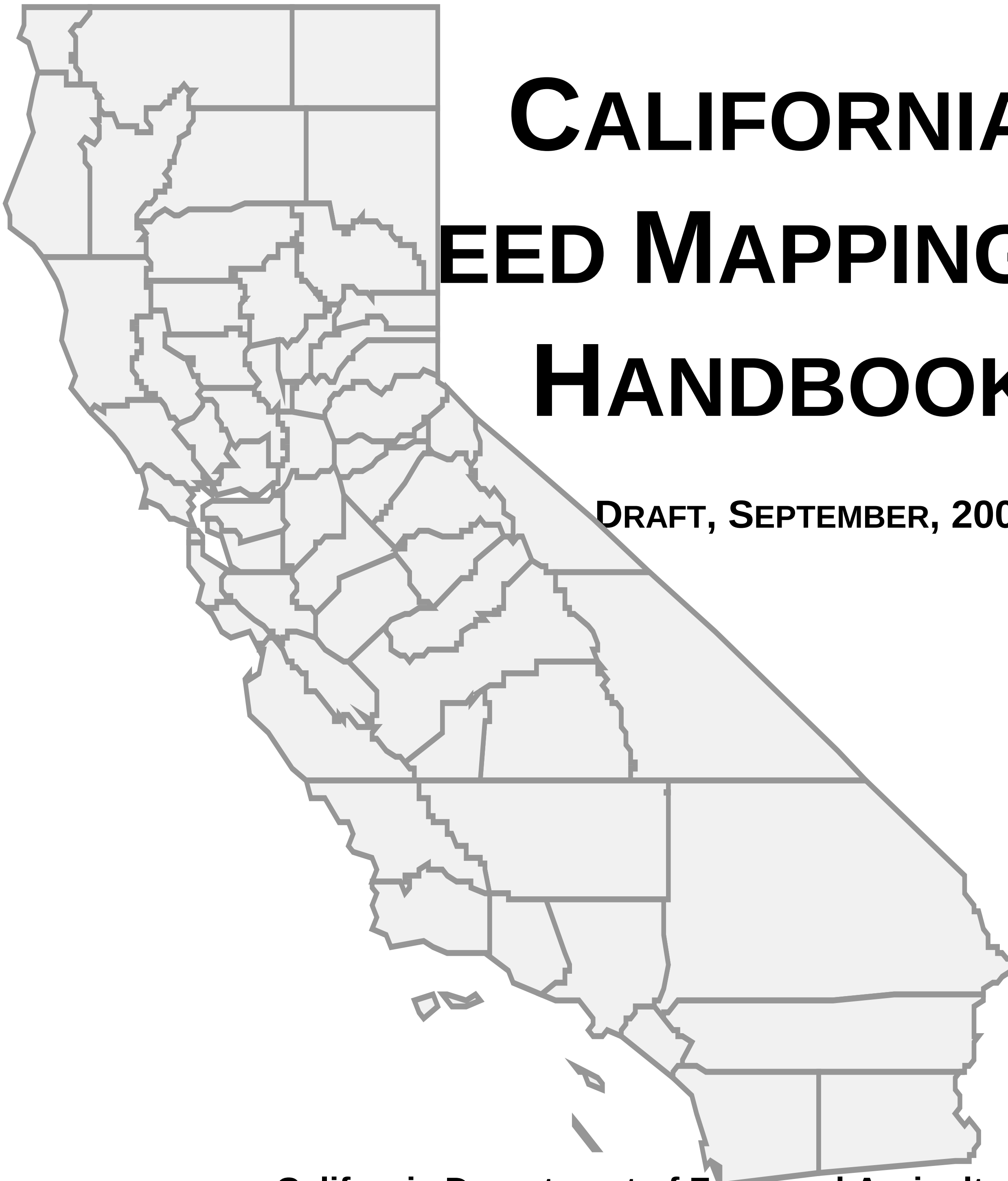

CALIFORNIA
EED MAPPING
HANDBOOK

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California Department of Food and Agriculture

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Purpose of the handbook

This handbook is a training resource for local groups (such as Weed Management Areas) involved in wildland weed mapping. It has two purposes: (1) to provide shared data standards, so that different data sets will be compatible, and (2) to provide "how to" instructional information on mapping techniques. The aim of this guidebook is to help those working on weed issues to develop mapping systems that will support project goals on both a local and state level.

What's in the handbook

The first section of the handbook gives background information on mapping, covering topics such as map projections and spatial coordinates.

The second section presents data standards. This information should be used to develop your own mapping system—what data you will gather in the field, what format to store it in back at the office, etc.

The third section presents an overview of instructional materials for mapping weeds. Topics include hand mapping, the use of GPS units, and GIS software.

The fourth section contains documents on standards, more in-depth instructional materials addressing specific topics, and examples of actual mapping programs. These are referenced in the narrative of the other sections.

Who wrote the handbook

This handbook was developed by a team of weed mapping practitioners led by the California Department of Food & Agriculture. The team included specialists from the USDA Natural Resources Conservation Service and the UC Cooperative Extension. Several nonprofit organizations and county agricultural agents were involved as well.

How YOU can contribute to the handbook

This first published version of the handbook is a working draft. As such, it will benefit greatly from active input from the California weed mapping community. Tell us what sections are hard to understand, what other information you would like to see in the handbook, which URLs don't work, etc. Comments can be sent to the authors via Steve Schoenig at sschoenig@cdfa.ca.gov.

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Section 4: Resource Appendices

Contents of Included Disk

CDFA Weed Observation and Monitoring Form (MS Word)

CDFA Weed Data Spreadsheets (MS Excel)

INTRODUCTION TO THE HANDBOOK

THE BENEFITS OF WEED INVENTORIES

With limited budgets for weed management, it can seem hard to justify spending time and money on weed inventories or maps. Wouldn't that time and money be better spent toward actual weed management?

The best justification can be found in Steve Dewey's brochure, *Noxious Weeds: A Biological Wildfire*. Dewey applies wildfire management principles to invasive weed management. When fighting fires, the first priority is to contain the fire and extinguish spot fires outside the perimeter of the fire. Trying to fight a wildfire without any idea of its size, direction of spread, rate of spread and other relevant information, would be a much less effective use of the efforts of firefighters (and could potentially jeopardize their lives).

Likewise, trying to manage an invasive weed infestation without relevant information reduces the effectiveness of control efforts and wastes time and money. But armed with maps and inventory information, weed managers can develop strategies focused on removing new and isolated infestations while containing the principle infestation—the same strategy used for wildfires. Once the infestation has been contained, it can be further reduced by working from the outside in.

In addition to enabling weed managers to prioritize which part of an infestation to treat first, the use of invasive weed inventories can increase the efficiency of almost any method of weed management. For instance, weed managers might combine weed inventories with information on soil type and water table depth to select the most safe and effective herbicide for a given location. Or they might keep inventory information to help plan and track volunteer weed pulling efforts. No, inventories and maps will not themselves kill weeds, but they are invaluable planning tools that help us get the most out of limited weed management dollars.

Maps and inventory information are also critical to monitoring efforts. No matter what tool is used to manage weeds, monitoring should be done to evaluate the effectiveness of the efforts and to make sure the area has not been re-infested. Many weeds have seeds that remain viable longer than can realistically be tracked by memory. Many county weed supervisors know from personal experience where every weed infestation in their county is located. But when these individuals are no longer available, their knowledge will be lost unless it is recorded in a way that enables subsequent staff to work from it. Otherwise, should anything happen to these people, the epitaph on their headstone might read, "Here lies the county's entire weed inventory." By putting this information onto paper maps or into computer databases, weed management efforts can continue past the duration of a particular person's career.

One of the most important benefits of weed inventories lies in their use as a tool for generating awareness. If a picture is worth a thousand words, a map is worth a thousand reports. Whether the audience is county commissioners, state legislators, congressmen, special interest groups, or the general public, being able to tie the problem back to their geographic area of interest dramatically increases their receptiveness and interest in the problem.

Currently, encroachment by invasive species is the second largest contributor, after habitat loss from land-use conversion, to native species becoming threatened and endangered species. Invasive weed inventories provide the data necessary to further quantify impacts of invasive weeds on native ecosystems.

WHY MAP?

IN A NUTSHELL:

- To provide a framework for area-wide and site-specific management plans
- To set strategic goals and priorities
- To monitor project success over time
- To increase public awareness
- To influence public policy
- To predict areas potentially subject to

SHARING DATA FOR COORDINATED MAPPING

Mapping is important on many scales. On the local level, inventories and maps help weed managers prioritize their work. On the regional level, local groups might share their maps and inventory data to inform coordinated control efforts. And on a state level, the collective data from all local groups can help assess the extent of particular weed problems.

To facilitate this type of interaction between different data sets, weed mappers need "shared data standards." These are general formatting and content guidelines that make sure everyone collects at least a certain basic set of data, and records it in a way that will be easy for others to use as needed. This effort is not intended to create a single master database, but rather to create many databases throughout the state with minimum standards so that all information being collected is compatible. There will be many ongoing needs and opportunities to bring together local data for statewide, national, or even global maps.

FREQUENTLY ASKED QUESTIONS

Can we really map all the weeds in our county?

Of course not. There are some 1,200 non-native plants that have become naturalized in California. Most are not invasive or high-impact. Regional inventories need to be prioritized and focused on strategic goals. There is only time to map important weeds in any detail. Often rarer weeds need to be mapped more accurately than the wide spread ones.

Why isn't GIS more straightforward?

GIS is a complex science involving knowledge in three major areas: geography, computer science, and a subject discipline such as invasive species or land use planning. Issues such as those presented by a huge array of hardware and software choices, a multitude of data formats, the many coordinate systems and data projections, finding and getting appropriate data, and a myriad of analysis techniques and sources of error, make GIS a skill set that takes years to fully develop.

Isn't GIS only for experts?

GIS software has gone from being available only on mainframe computers to widespread availability on the common desktop computer, and so there are many more users and applications. With these more accessible tools it is possible these days to become, with diligence in a fairly short time, proficient enough at the basics in order to use the technology to inform project planning. Nevertheless it is good to recognize that there's a lot to know and that a recent initiate should seek help troubles and pitfalls.

Aren't paper maps good enough? Why all the technology?

Paper maps are the tried-and-true method. They are still a good, reliable way of displaying data and often are still the best way to record data in the field. However, paper maps fall short when it comes time to store, analyze or to share data. This is where the capability of GIS technology comes in. GPS units assist us in our data creation by allowing us to collect location data in ways that are easy to add into a GIS computer project.

CARDINAL RULES OF WEED MAPPING

1. ***Map efficiently.*** Use a level of detail in mapping weeds appropriate to your goals and the distribution of the weed in the region. Don't over- or under-map weeds.
2. ***"Steal with pride."*** Don't reinvent the wheel—if someone else has already come up with a good solution to a problem you are facing, put it to use. Likewise, share your own resources freely.

3. ***Also map where weeds are* not *found.*** It is just as important to map where you didn't find weeds as where you did (in other words, collect data on the entire area searched) and make absence reports when possible.
4. ***Respect private property.*** So not trespass onto private property to map weeds without the owner's permission.
5. ***Record field data promptly.*** Once back from the field, process your collected data quickly before it piles up and your memory fades.
6. ***Keep data organized.*** Record the data on your computer carefully, giving files useful, logical names. Create organized directory structures that allow quick retrieval of data.
7. ***Write down metadata***. Keeping track of the key information about your dataset for all weeds datasets is crucial for future data use and interpretation.
8. ***Be careful with codes***. Use codes and abbreviations with caution, since they are often hard to understand later, especially by persons who did not collect the data. If you must use codes, keys should be associated with the data.
9. ***Know your projection***. When sharing digital mapping data from a GIS or exporting GPS field data to a GIS format, you need to know the projection and datum being used. (Keeping track of metadata is a good way to ensure that this is never too hard to figure out.)

SECTION 1: BACKGROUND INFORMATION ON MAPPING

SECTION ORGANIZATION:

1.1 Overview of Techniques and Tools

Hand-mapping

Mapping by hand is a "tried and true" method of tracking locations of weed infestations. By drawing onto printed maps—such as USGS quads, park trail maps, or aerial photos—one can easily mark locations for various features of interest.

Guidance on techniques that have been developed for hand-mapping is presented in Section 3.1 of this handbook. Sample forms for use in collecting data in the field along with hand-drawn maps or GPS units are found in Section 4.1.

Maps with hand-drawn information should be stored and recorded such that they are available for future use. Hard copy information can later be converted for use in a computer by using scanners or digitizers (see Section 3.4). Hand-mapped data can also be stored digitally using mapping software such as TOPO! (discussed later in this section; also see Section 3.2)

Global Positioning System (GPS) units

GPS units have become a common way to collect location data. By receiving signals from a network of satellites, GPS units are now providing accurate location information in a variety of applications.

Until the last few years, data from the satellites was deliberately downgraded by the U.S. military to impede accurate real-time location measurements. Because of the removal of this scrambling, called Selective Availability or SA, it is now much easier for the public to use GPS technology. For high levels of accuracy, measurements still need to be corrected for atmospheric conditions and irregularities in satellite orbits. Called differential correction, this is accomplished by referencing a nearby "base station."

GPS EQUIPMENT COMPARISON

Grade	Accuracy	Cost
Recreation	10m	$200
Mapping	1m	$5,000
	sub-meter	$10,000
Survey	0.1m	$20,000

[All figures approximate]

There are many choices of GPS receiver units that differ in features and capability for accuracy. Terminology referring to these categories varies widely but are usually discussed as falling into classes or grades based upon the usual intended use. "Recreation grade" is the term we use in this handbook for GPS units sold mostly for outdoor recreational activities or activities that require only that you can navigate to the object to within sight, "mapping grade" for those used in general land inventories and often in research projects where more accuracy is important, and "survey grade" for surveying tasks that require very high accuracy, such as bridge construction. Mapping-grade units can be further thought of as sub-divided into those that have the capability of about 1-meter accuracy and those capable of sub-meter accuracy due to differences in receiver and antennae instrumentation. As the chart at left shows, increasing accuracy comes with increasing price (these costs reflect other features as well).

Recreation grade GPS units, such as Garmin units, have the advantage of being inexpensive, commonly available, and user-friendly. The relatively low level of accuracy (between 5 and 15 meters under favorable conditions) is generally adequate for weed mapping. Most of these units can store the locations of points and download those to a computer back in the office. Otherwise you need to write down coordinates. Major differences between these units and mapping-grade units include: (1) the recreational- grade units allow the collection of point data only (no line or polygon features); (2) they are not designed to store data in a GIS-ready format such as a shapefile for ArcView, allowing data generated in the field to be automatically transferred into a GIS system on the computer; and (3) you will not be able to use the unit alone to digitally collect descriptive (attribute) data together with your geographic data. There are certainly options for solving these challenges, however, such as software packages that convert simple waypoint coordinates into data that can be used in a GIS program (see Sections 3.2 and 4.4). The use of recreation-grade GPS units for weed mapping data collection is discussed in Section 3.2.

Mapping-grade GPS units, such as the Trimble GeoExplorer 3, not only have the capacity for higher accuracy but are designed to facilitate data collection for a GIS program. Features can be captured as points, lines, or polygons. By programming a "data dictionary" you can design menus for the features you expect to encounter (such as "Yellow starthistle patch" and different density classes). Use of mapping-grade GPS units for weed mapping data collection is discussed in Section 3.3.

Garmin III Plus
(recreation grade)

Handheld computers (PDAs)

GPS accessories specially made for handheld computers are currently being sold, and it is also possible to connect a recreational- or mapping-grade GPS to a PDA such as a Palm OS device, Windows CE PDAs, or the more expensive and full-featured Compaq iPaq handheld computer. When coupled with special data capture and display software such as ArcPad, handheld computers are becoming a versatile and cost-effective (full set-up is on the order of $1,500) option for collecting digital, GPS-ready data in the field. Hardware and software combinations are many, along with the amount of set-up time and technical support required for their use. Use of handheld computers for weed mapping data collection is discussed in Section 3.4.

Trimble GeoExplorer 3
(mapping grade)

Mapping software

Mapping software packages, such as TOPO!, provide a background map (made from USGS quads) upon which you can mark locations of weed infestations. You can do this by simply drawing your features over the map using your mouse, or by entering spatial coordinates directly from your GPS that the program then places on the map. Advantages: There is almost no start-up time and very little technical expertise required to make very nice maps that are useful in presentations and documentation. The software handles the data directly from the GPS; there's no need to convert the coordinates from your GPS into a GIS format. Downside: You have little control over symbols used, and there is no capacity for storing information about the features as there is in GIS software.

Rockwell PLGR (early vintage
military; used by NRCS)

Geographic Information Systems (GIS)

GIS programs, such as ESRI's ArcView, are database applications with the capability of displaying and analyzing spatial data. They display two kinds of data—vector and raster—that are described later in this section.

GIS is becoming the standard way to store land management data, because it provides a way to keep track of a lot of information, to analyze the relationships of different types of data (such as geological substrate and vegetation), and to display the data as maps.

GIS software allows weed managers to organize inventory data and use it for developing control priorities, monitoring control progress, and displaying results. Data stored in a GIS can be easily shared, whether between agencies within your local government, or neighboring jurisdictions, or state-level weed managers. This makes it a powerful tool for addressing the problem of invasive species.

The use of GIS for weed management is discussed in Section 3.5.

Remote sensing

Remote sensing refers to the acquisition of data from afar, typically from airplanes or satellites. Aerial photos are one common example of remote sensing data familiar to land managers. Multispectral aerial and satellite imagery is another form of remote sensing with applications to land management. It has been used for agricultural purposes (for instance, to assess crop types), and is becoming more useful for weed management applications as techniques for mapping weeds are developed. Remote sensing imagery is raster format data (see discussion later in this section).

1.2 Projections, Datums, and Spatial Coordinates

Mapping by nature involves the task of making a round world flat. Representing a three-dimensional object—the Earth—on a two-dimensional surface—paper or a computer screen—requires the use of a mathematical process called a "projection." While the spatial coordinates of latitude and longitude, measured in degrees of a circle, work well for pinpointing locations on a sphere, they do not translate well to a flat surface (the classic analogy is peeling an orange and trying to make the skin lay flat).

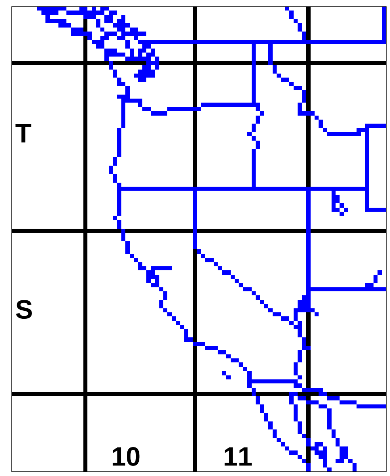
To make things more complicated, the planet is not actually an exact sphere, but an "oblate spheroid." (The diameter of the globe from pole to pole is smaller than the diameter across the equator.) Thus we model the three-dimensional surface of the earth as an "ellipsoid."

A "datum" is a base point for the ellipsoid that we use to model the earth's surface. The datum determines the placement of the coordinate system upon the ellipsoid, defining the origin and orientation of lines of latitude and longitude. There are two kinds of datum—a geocentric datum is centered on the earth's center of mass, and a local datum is slightly offset to a convenient location in order to accommodate a particular region of study. The North American Datum of 1927 (NAD27) is a local datum still used for many U.S. maps. The North American Datum of 1983 (NAD83) is a geocentric datum based on the most current measurements of the shape of the earth (WGS84 or GRS80). (This section is adapted from information found at <www.fgdl.org/tutorials/howto_reproject/MapProjectionBasics.html>.)

There are many projections and coordinate systems that have been developed over time by cartographers, each designed to be most accurate in specific regions. Several of interest to California weed mappers are discussed below.

Universal Transverse Mercator (UTM): UTM coordinates are in the form of "Northing" and "Easting", the number of meters north of the equator (in the northern hemisphere), and east of a meridian selected for a particular zone. Zones are 6 degrees east-west by 6 degrees north-south. California is in UTM zones 11S, 10S, and 10T (see figure at right). Because UTM coordinates are in meters, they can be much easier to work with on the ground than degrees latitude and longitude, especially when distances are important.

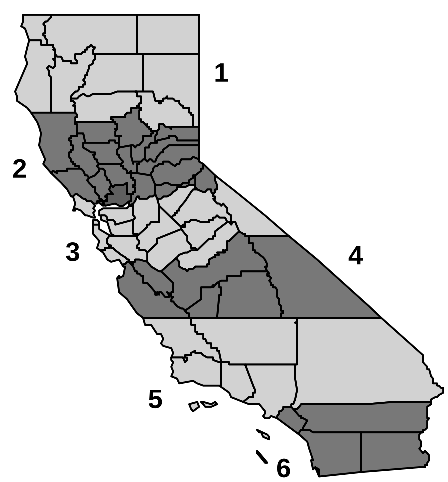
UTM Zones in California



State Plane Coordinate System: "State plane" is not truly a projection but a coordinate system that came into use in the United States in the 1930s when the United States Coast and Geodetic Survey used it to provide a common reference system for surveyors and mappers. The country is divided up into 120 zones—California's zones are shown in the figure at right. As with UTM, coordinates are in the form of northing and easting from specific north-south line and an east-west line.

Many county and municipal governmental organizations use state plane for local mapping projects. This makes it a useful choice for local weed mappers, so that their data easily meshes with other county data. GIS layers that counties often already have (for parcels, jurisdictions, roads, etc.) are useful as base layers for weed mappers, so it is often simplest to use this system for your weed GIS.

NAD83 State Plane Zones in California



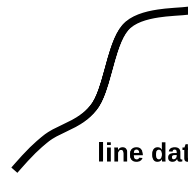
California Teale Albers: California state agencies sometimes use this special projection for their work. It is a projection that is optimized for California, but it has the disadvantage of being uncommon. You probably do not want to design your GIS in this projection, but you may get data from the state in this format.

When you have data in multiple projections you need to "reproject" data. Typically you will decide what projection to build your weed GIS around, and then reproject any data in other projections to match your system (also know as co-registration). This operation is performed automatically by some GIS software, while other software requires that you use special software extensions, such as the Projection Wizard in ArcView 3.x.

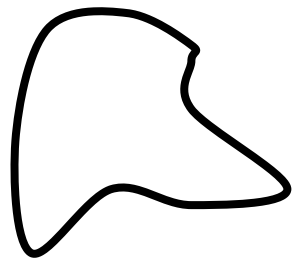
1.3 Vector Data—Points, Lines, and Polygons

There are two fundamental approaches to representing spatial data: the vector data model and the raster model. Vector GIS data consists of "features" that have "attributes." A feature is any object that you want to define in the landscape—the location of a gate, a segment of road, a patch of weeds, etc. Attributes are any information you want to store for a given feature—its name, the date the location was taken, its condition, etc. These attributes are stored for future reference, and can be used as the basis for analysis as well (for example, one could sort out all *Arundo* patches within quarter-mile of a stream). Features in vector data are represented by points, lines, and polygons. In the example above, the location of a gate would be represented by a point, a segment of road with a line, and the weed patch with a polygon.

point data



line data



polygon data

1.4 Raster Data

In raster data such as a scanned photo or drawing, a digital satellite image, or a GRID coverage in ArcView, an area is divided into rectangular sections called pixels. The number of pixels contained in an image per area unit is known as the spatial resolution of the image. Each pixel has a value. For instance, an aerial photograph that has been scanned as a black and white image is made up of small rectangles that are black, white, or a shade of gray. In this case the numbers in the data refer to the proportional amount of light reflected by (the brightness) of the pixel within some range of the spectrum. In color imagery there are three or more layers of the same image with pixel data for different parts of the spectrum such as red, green, and blue. When viewed together these make up the many colors we perceive with our eyes and allow us to more effectively visually interpret the features in a photo.

Often geo-referenced raster data is used as background imagery for GIS mapping. Some commonly used raster datasets are:

- Digitized aerial photographs called DOQs (Digital Ortho Quads)
- Digitized images of USGS topo quad maps called DRGs (Digital Raster Graphics)
- Shaded relief images that are created from elevation data from files called DEMs (Digital Elevation Models)

Raster and vector data are discussed further in Section 3.5.

SECTION 2: SHARED DATA STANDARDS

SECTION CONTENTS:

2.1 Background on shared data standards

Data standards are necessary when data is being collected that may potentially be shared with others or combined with data collected at other times. A common format allows data collected by different organizations to fit together with a minimum of effort. In addition, established data standards help new data collection projects avoid many common mistakes.

In the overall effort to control weeds, there are some very compelling reasons for sharing data, from the regional level to the global level.

We know that weeds do not recognize property lines or jurisdictional boundaries. For regional weed managers to work effectively with different property owners and neighboring jurisdictions, it is important to be able to share inventory and mapping data.

By definition, invasion by alien species is a global problem. Ideally, invasive plant control would be supported by constantly updated information on the big-picture status of invasions. In order to gain full perspective on the movement and density of invasive species, we need a large number of surveyors and a means for rapidly combining their observations into a common database. With enough data and the ability to share it quickly, valuable new information services can be created, such as early alert systems and predictive modeling. These will enable better-informed weed management decisions, and also present political decision makers with a more clear idea of the threat posed by invasive plants.

There is widespread recognition among land management agencies that sharing invasive species data is of the utmost importance for stemming the tide of this environmental catastrophe. This consensus is evidenced by the recent proliferation of national and international declarations, groups, and efforts toward the goal of sharing and combining data. The Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW), the Global Invasive Species Programme (GISP), and the many regional Exotic Pest Plant Councils are just a few of the groups that have worked on standards and examples of data sharing.

Many of these programs have begun to develop online databases, and there is a concentrated effort to coordinate the rapid, open exchange of data on a global scale. Data standards are at the core of this work.

NAWMA, the North American Weed Management Association, has developed a weed mapping content standard called *The International Standards for Inventory, Monitoring, and Mapping of Invasive Plants*. The data standards presented in this section of the handbook for California weed mappers is based on the NAWMA standard with the addition of a data structure and the keywords and pick-lists that will be useful in California. The table in Section 4.2 ("A Comparison of the NAWMA and CDFA Data Standards") shows the two data standards side by side.

KINDS OF DATA STANDARDS

These standards help different organizations combine datasets and analyze them together meaningfully.

Content standards
These give consistency to the names and definitions of data fields and the attributes assigned to them. They make it possible for different data collectors to "speak the same language."

Sampling protocol
These give guidance for collecting field data. which helps multiple observers create consistent datasets.

Data structure
This standard specifies the way data is organized in a database. It makes it easier to combine data from different kinds of databases into one database.

Data format
This is a standard for actual file type, which makes combining data much easier. The "Shapefile" format is a common example for ArcView GIS users. "XML" is a more generic format that is not associated with a particular software package.

2.2 Core weed information to collect

The data for which we need a standard is straightforward and contains those elements everyone will want to collect: what weed was observed, how much of it there is, where it is, who owns the land, who saw it, when they saw it, and how accurately they mapped it. The role of a standard is to make this data collection consistent across observers and organizations.

The following describes the standard data content elements that we have developed for California weed managers. The first part of the list describes categories you will need to collect when in the field. The second part of the list describes categories that could be recorded in the office, whether before the field outing or upon returning. See also Section 4.3 "Summary of Minimum Requirements for Weed Mapping."

In the field

Collection Date: The full date on which the infestation was observed should be written on all paper forms in the format YYYYMMDD (or one you could convert to that format when it comes time to share the data). If you are using a GPS unit, the date will be automatically stored with each observation.

Observer: The full name of the person who observed the infestation should be written on all paper forms.

Site Name or ID, any site description information: Record a name for the site or an alphanumeric identifier and also put this on your hand-drawn map. Make any observations describing the site while there.

Genus/species: The scientific name for weeds should be used to avoid confusion. If you are using a mapping-grade GPS with a data dictionary, or digital form, you can create a menu to choose from. The Jepson manual, the CalFlora database (online at <www.calflora.org>), or the Integrated Taxonomic Information Systems (ITIS) can be used as sources of current scientific names. If you use a common name in the field you will need to translate it when you are back in the office.

Presence/Absence: This is implied as “presence” when there is information describing an infestation (such as cover class), but a simple absence report can be made for an area as well by stating the species and indicating the location, and saying it is “absent.”

Gross Area and Infested Area: “Gross area” is an estimate of the size of the general region where the weeds occur and may be used when precision is either unnecessary or impractical (see further discussion of this in the Yellow starthistle case study, Section 4.8). An example of the use of gross area is the identification of a 40-acre property that has weeds in large patches, but also has un-infested areas. The fact that the observer put “40 acres” in the gross area field correctly conveys the fact that a detailed survey was not done. This associated with average cover density of the weed is a quick way to note the presence and severity of an infestation.

In contrast,” infested area” is an estimate of the size of the *specific* region in which the weed occurs, mapped more carefully by thoroughly observing the site and estimating the area of the land covered by the weed (whether it’s sparse or dense cover).

When hand mapping, we recommend the use of point symbols (shown at right) to mark infestations under five acres. For infestations five acres and larger, draw the areas onto the map (assuming you are using a map with 1:24,000 scale such as a USGS topo quad). Avoid drawing areas or lines if there are not clear reference features by which to judge location, as it may be misleading. If you use colors or abbreviations as codes (to indicate the type of weed, for example), be sure to write a key to the code on every document where the code is used.

If you are using a GPS unit to measure location, you should record the size of the infestation in acres.

Canopy Cover: Canopy cover is percent of the infested area covered by the weed being surveyed. One way to think of this is to visualize all of

HAND-MAPPING SYMBOLS

✕ <0.1 acre

△ 0.1-1 acre

□ 1.1-5 acres

the weeds pushed together until their canopies touch, and then estimate this area and the portion of the overall infested area that this represents. Classify the cover into one of the categories listed at right.

National Ownership, Local Ownership: Record the national ownership code, as listed in the table on the following page. State ownership codes may also be developed in the future. Local ownership can be recorded as the name and contact information of the party who owns the property for future reference.

Geographic Location: If you are hand-mapping, indicate on your map with the desired symbol and give the feature an identifying alphanumeric identifier. Put this feature ID into the form that contains the descriptive information for that location. If you are writing down coordinates from a GPS unit, be careful of transcription errors as small numerical mistakes can translate into big geographic errors. It's helpful to stick with one coordinate system displayed in a consistent format, know what those numbers should look like, and always mind your decimals.

If you are storing points in your recreation-grade GPS unit, or points, lines, and polygons in your mapping-grade GPS unit, your location data is stored digitally. GPS data is automatically stored by the unit in the pre-chosen format, the default of which is usually latitude and longitude in WGS84. Once this is downloaded to your computer, you can convert the data into any projection you need. If you are creating polygons or line features with a GPS, the data is more complex and will be handled entirely in its digital form.

Coordinate System and Datum: Record the coordinate system in which you are recording data. This includes the projection and datum—for instance, UTM Zone 10 NAD83. It's best to set this up in advance, whether by choosing the coordinate system that is displayed by the GPS unit, or decided how coordinates will be taken from a map.

Location Accuracy: Location accuracy refers to the closeness of the coordinates recorded to the real-world location (which can also thought of as the "fuzziness" of the data). High accuracy in location reporting is not always necessary or desired- the important thing for future data interpretation is to record it, whether it is high or low! Location accuracy takes both the accuracy of the mapping method and the intended exactness of the location data into account for a number that indicates how much error or fuzziness should be considered part of the data. Note: "precision" and "accuracy" are different- precision essentially refers to the number of decimal places, so a very high-precision GPS instrument can give you a high-precision location number with 6 decimal places, but still be inaccurate as far as its closeness to the real-world location you're trying to record. See the paragraph on accuracy in the GPS section (3.2) for information about factors that effect accuracy.

COVER CLASSES

(BASED ON DAUBENMIRE)

Cover Class	Range of Coverage	Midpoint of Range
TRACE	<1%	--
1	1- 5%	2.5%
2	5- 25%	15.0%
3	25 - 50%	37.5%
4	50 - 75%	62.5%
5	75 - 95%	85.0%
6	95 - 100%	97.5%

NATIONAL OWNERSHIP CODES

Listed below are codes that are likely to be useful in California. For a full list, see Appendix C of the NAWMA guidelines at www.nawma.org. This webpage includes information on specific tribal codes for reservations.

ARS	Agricultural Research Svc.
ALOT	Native American Allotments
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Mgmt.
CGOV	County-owned lands
DOD	Department of Defense
NPS	National Park Service
NRCS	Natural Resources Conservation Svc.
PVLA	Privately-owned lands
STAT	State-owned lands
TNC	The Nature Conservancy
TRIB	Tribal lands
UNIV	University lands
USFS	US Forest Service
USFW	US Fish & Wildlife Service
USGS	US Geological Survey
USOT	US Government - Other

Location Offset: Location offset is the direction and distance to the target location. Sometimes you can't stand right on the clump of weeds, but you'd like to record which way and how far to look when you get to that waypoint.

Weed Description Information: The parts of the form that describe the weed infestation, appearance/phenology and distribution pattern, along with documenting photos, should of course be filled out while in the field. Use the pick-lists for descriptors as presented in the sample field form.

ERROR ESTIMATES

Use these broad classes:

- <1m
- 1-5meters
- 5-15 meters
- 15-100 meters
- 100 meters-1 km
- 1 km-10 km
- >10 km

The accuracy ranges from 1 km to more than 10 km are useful for indicating that a data point represents the center of a large area in which the weed is known to be present.

Examples of error estimates

1) Joe Weedman observed some *Arundo donax* while driving to work. In the office, he made a report, assigning an approximate location for the infestation by taking coordinates from a quad map shown in TOPO! software. Joe decides to assign an error of a few hundred meters to the observation.

2) Joe returns to the infestation a week later with his Trimble Pro-XRS mapping-grade GPS receiver. He maps the single clump of plants by standing right in the clump. The GPS point is meant to indicate the exact location, and under perfect conditions this instrument can provide sub-meter accuracy, but Joe couldn't stay long to get the recommended 180 readings, and his PDOP was high. He decides that an error of about 10 meters is appropriate.

In the office

Make sure to record the following information. It is not critical to record this information in the field—it can be done in the office (promptly) after the field work.

Observer Contact Information: This may be the same as the organization contact information, and so you won't probably need to write it on every form. The purpose of this information is to allow for contacting the observer should there be questions about the data later on. Keep contact information up to date.

Source of Data: Record the full name of the agency or organization responsible for collecting the data. If the agency has a national ownership code, that may be used. Again important mostly when you decide to send the data to someone outside the organization.

County: Record the county name, or the state code, or the six-digit FIPS (Federal Information Processing Standards) code for your county. A table listing these two systems of codes along with the county names can be found in Section 4.6.

HUC Code (for aquatic weeds only): Look up and record the Hydrologic Unit Code for the watershed in which the aquatic weed occurs. See the USGS HUC website at <http://water.usgs.gov/GIS/huc.html>.

2.3 Forms for data collection

As mentioned above, we've included with this handbook a model form for collecting data in the field (found in Section 4.2). The form is designed for recording all of the above information. The form can be used "as-is" to collect this data together with hand-drawn maps or GPS data (or both). The form can also be used as a template for designing your own custom paper form, GPS data dictionary, or electronic form on a PDA.

2.4 Storing data in spreadsheets, databases, and filing cabinets

Storing the data from the field forms

Even if you are doing your mapping entirely on paper, it is suggested that you enter your weed observation data into a simple spreadsheet, and when you do that to create the metadata that is so important for keeping track of it all. Taking this step *as soon after collecting the data as* possible is a good data management habit that will serve you well. On the disk at the back of the handbook, we've included an Excel workbook file containing a group of simple spreadsheets with the basic fields for recording data from the paper field forms. The fields match the standard as discussed above. Doing this will not only help you know what data you have, it will enable you to share your information with others.

The sheets in the Excel workbook are called: Observer Contact Information, Metadata and Site Description, Weed Observation, and Photo Log. All of these are sections in the standard, and could have been put into a single spreadsheet. The reason for creating separate sheets is to avoid having to enter data many times when it can be entered once and used multiple times by referencing its ID number- the basis for a relational database. Until a database application is developed with forms for data entry, it is up to you to use the keywords recommended in the model form. The workbook and its spreadsheets could form the template for such a database in software such as MS Access. ArcView can be set up to communicate with the Access database tables, allowing for the descriptive records to integrate with the geographic information display and analysis abilities of a GIS. Digital forms would help with mistake-free data entry (and auto-generation of the all-important IDs). These developments are likely to be done in the near future for all to use.

As you can see, data can be migrated from the simplest low-tech, paper set-up into simple computer spreadsheets and then into full-fledged GIS a little at a time, if you are careful about things (especially those IDs that link the information across the sheets). If you follow the standard, your data will migrate gracefully when it's time to do so. It is a perfectly good solution to make paper maps and use the paper field forms, enter the data into the spreadsheets and graduate later to more advanced techniques. We do recommend that you get an inexpensive GPS and learn to use it, and use the Excel workbook from the beginning. Even if you have never been a computer "whiz", you will graduate quickly into handling the GPS data through the computer and making maps with software like TOPO!, and then into the use of ArcView to do more with your data. Don't be afraid to call upon others for advice and demos--the best way to learn these skills is by being shown by someone who has figured it out already.

Storing your hand-drawn maps

Your paper maps will come in handy as references far into the future, and so a well-organized filing system is a must to ensure they are found and useable by you or others. When combining the filing of hard-copy materials with associated files on a computer, make an effort to reference folders the same way in both filing systems.

Storing your photos

You can store print photos just like you do your maps, by writing dates, features, and reference numbers on the backs or pasting them onto a page with notes. Annotate and file print photos carefully with paper maps, being sure to make the notes soon after returning from the survey. Storing photos digitally is an even better way to go, and a digital camera makes this easy, skipping the photo development step and letting you download photos from the camera directly to your computer. A conventional film camera works too, though, as you can have the film developed directly onto a CD. The CD is a convenient way to store the photos. Label CDs carefully with the date and the names of the sites photographed in permanent marker. You won't be able to rename the image files on the read-only CD, but you can use the filenames already there plus the survey date to reference your photos uniquely in the corresponding data spreadsheet. See the instructions and example on the Excel spreadsheet template included on the disk with this handbook.

Digital image formats are jpeg, png, and tiff. The jpeg format has a built-in compression method that is "lossy" (some information is discarded when the image is compressed), while png and tiff are not lossy but also not compressed. Most digital cameras create jpegs, and the size of the image will depend upon the resolution setting in your camera when you take the picture. If image resolution is high, the files will be large, and you will probably want to make smaller copies of the image for use in slide shows and on the web. Keep the large originals, storing on CDs if they take up too much of your computer's hard-drive space.

Naming conventions

The names of folders and files that contain project data, survey date, and site names will help you link everything together if you use consistent naming conventions. For example, suppose you have a computer folder that contains the digital photos and the Excel file, and a hard-copy folder that contains the maps, all from the same survey. Both folders are called "Cosumnes080502" (after the site and the date), and within the folders the contents are named with specific site names and dates, such as "LowerReach080502.xls" for the data file,"LowerReach080502_Photos" for the folder with the photos, and "Cosumnes Lower Reach 080502" is part of the title of the map. Putting everything together by site and date is better than filing by type (like all your photos in one file, and your maps in another).

It will be important that you can tell one site from another by its name, and that the data file names, even when abbreviated, easily tell you which site they relate to. Decide on an internal file naming convention that lets you uniquely abbreviate the names of sites so the filing system is easy for anyone in your organization to access and understand.

SECTION 3: INSTRUCTIONS ON MAPPING TECHNIQUES

SECTION CONTENTS:

3.1 Collecting map data using hand-mapping techniques

Invasive weed plants or populations that have been surveyed can be hand drawn onto any printed map (for example, a printed and enlarged copy of a USGS quad map). Examples of printed maps are: USGS 7.5-minute topographic quad maps, US Forest Service 15-minute quad maps, local AAA road maps, county "blueprint maps," assessor parcel maps, and Thomas Bros. Maps. Marks on a map can be correlated with waypoints made with a GPS by writing the waypoint number on the map. The hand-drawn data can be added to ArcView or ArcGIS via one of a number of digitizing techniques, or the hand-drawn maps can be kept as information that augments computer files containing GPS point locations and weed descriptions.

Map the type and size of the infestation

Point infestations should be identified by an X, a triangle or a square drawn directly on the base map. Use black or red ink. (Areas greater than five acres should be drawn as a polygon.)

X	less than 0. 1 of an acre
△	0.l to l acre
[]	l to 5acres

Line features can be used when weeds follow linear features such as roads or streams. The lines can be any length. When identifying lines, include the line width (real world width of the infestation) and center the line on the middle of the infested strip.

Infestations larger than *5* acres should be outlined on the map. A square, five-acre infestation is approximately 467ft on a side. Therefore, a five-acre infestation drawn on a 1:24,000 (7.5 minute) topographic quad map would be about ¼ in. or 0.6cm on each side. Since most weed infestations aren't square, do your best to draw an area that will depict the infestation's true size and shape. If there are not features on the map (like rivers or contour lines) that you can use to delineate your area, it may be more accurate to use a point to represent the infestation and then write an acreage estimate.

Estimate weed cover class or density

Weed cover class is an important way to estimate and describe the density of target weeds being mapped. To determine cover class, estimate the percent of the ground that is covered by the weed. Estimate an average value if the density is variable, or draw separate polygons if areas of different density exist. Next to the map symbols write in one of the following cover estimates.

T = (Trace); less than 1% cover. A few plants

1 = (Low, occasional plants); between 1% and 5% cover.

2 = (Moderate, scattered plants); between 5% and 25% cover.

3 = (High, fairly dense); between 25% and 50% cover

4= (Dense) 50% to 75%

5= (Very Dense); 75% to 95%

6= (Solid Stand); 95% to 100%

Highlight areas surveyed where no weeds were found

For example, for Yellow starthistle, use yellow-highlighter hash marks for a section *with* YST. Outline the section in highlighter if you surveyed and did not find YST, and use no highlighting for un-surveyed areas.

[These guidelines are adopted from the Montana Noxious Weed Survey and Mapping System Handbook.]

3.2 Collecting map data using GPS

The Global Positioning System (GPS) is a navigation system consisting of 24 satellites orbiting the Earth twice a day and continuously transmitting information to ground-based receivers, enabling the receiver to compute its position. Originally developed by the U.S. Department of Defense, the system is now widely used by the public for navigation, recreation, and scientific purposes. Using the right equipment, you can find your location and elevation at any place on Earth, provided you have a relatively clear view of the sky.

This section discusses the techniques of GPS data collection, recording, and downloading for use in GIS software and data sharing.

Accuracy

One thing to remember when using a GPS receiver is that there will be some amount of error in the readings you record. The important thing is to have an idea how big that error is likely to be and what conditions affect accuracy so you know what you're getting. In section 1.1 we introduced the different grades of GPS equipment and discussed the levels of accuracy that they can be expected to provide with appropriate conditions and use. Here we provide more detail about that and what can be done to get the best location data from your GPS.

There are no hard and fast rules about what makes a "good" GPS reading. The data you collect needs to do a job, and different levels of accuracy are appropriate for different purposes. For example, a reading of the location of a large stand of weeds that is within 100 feet will be fine for the purpose of navigating back to treat the weeds. A research project that has the goal of matching weed locations with 4-meter pixels of an aerial image will need to have sub-meter accuracy, and the added expense and work to ensure this accuracy will be worthwhile.

Factors that effect GPS accuracy

A number of parameters affect the error in your GPS reading and therefore the accuracy of the number recorded. One of these is the number of satellites being received. A minimum of four satellite signals is required for trilateration (a process analogous to triangulation) of a three-dimensional ground position by computing the distance between the receiver and each satellite. With only three satellite signals, there are still two possibilities of your real location (only one of which will probably make sense). By adding a fourth satellite, it becomes possible to narrow down to one location. With less than three satellite signals, you will not get a GPS reading. Though GPS units differ, usually an “acquiring position” or “lost satellite reception” message will appear to tell you that the unit currently does not have enough information to determine your position. GPS receivers can only see satellites that are above the horizon, and obstructions caused by vegetation, buildings, your head, or canyon walls can block satellite signals. If your receiver cannot “lock on” to four or more satellites, changing your position (or the position of the GPS unit) often helps.

Once you have information from enough satellites, other factors will have an effect on the accuracy of the reading you get. If you are in an area with buildings or canyon walls there is the additional problem of the signal from the satellites bouncing off these surfaces before coming to the receiver, causing what is known as “multi-path error”. There is no measurement of this kind of error given by a receiver while you’re using it, and correcting for this kind of error can only be done in a post-processing step. The best thing you can do is stand as clear as possible from such obstacles, and when the situation is unavoidable simply consider the data less accurate than the receiver is reporting it to be.

Another factor is strength of signal: the stronger the satellite signal, the more accurate your GPS reading will be. This is also sometimes referred to as signal-to-noise ration or SNR.

The relative position of satellites at any given time is also a factor. PDOP, or Position Dilution of Precision, is a measure of error caused by geometry of the overhead constellation of satellites. The better the arrangement of the satellites your GPS can see—ideally they are in the four compass quadrants and not too high or low—the better the trilateration and the more accurate the resulting reading. Most GPS units display a number or graphic that relates to how well the satellites are arranged.

FACTORS THAT AFFECT POSITIONAL ACCURACY

- Satellite clock and location errors
- Receiver calculation errors
- Atmospheric effects
- Number and arrangement of satellites in view
- Multi-path errors

Things that can be done to increase accuracy

Being aware of the criteria for the best readings your GPS unit can provide is one step in getting the most accurate data for a situation. Some situations, however, are just challenging and you can’t do much more than get what you can and write down the estimated error. Mapping-grade GPS units allow repeated readings to be collected and averaged for a single data point, and collecting more readings will reduce error. These units allow you to set filters so that it won't average in readings taken when PDOP and SNR are above some minimum level. Statistical information can be analyzed in a post-processing step that further lets the technician decide about the quality of the data used in a location point. (This statistical information is available only from mapping-grade units, and is not available from recreation-grade units.)

"Differential correction" is the practice of further comparing the position data collected by the receiver to data collected by a base station receiver situated at a known location, and applying a correction factor based on this comparison. (The readings from the base station reflect inaccuracies due to current atmospheric conditions and satellite configuration, and thus help you correct for those.) GPS data can be differentially corrected either in a post-processing step back in the office, or "on the fly" while in the field (with the proper hardware), or both. Recreational-grade units aren't generally equipped with the hardware needed to collect the time-stamp information for either real-time or post-processed differential correction.

CORRECTION DATA FROM THE INTERNET

Correction data can be downloaded from various internet sites such as <www.fs.fed.us/database/gps/>. Use a base station located within 300 miles.

An estimate of accuracy should be recorded along with GPS location information, since this is an important component of GPS data. Recording the range of location error can make it easier to find the location again in the future, and it will ensure that your data is not misinterpreted or used for the wrong purpose down the road. When recording your GPS location, make note of estimated location error by selecting from the following ranges: <1 meter, 1-10 meters, or 10-50 meters. An "offset" can also be recorded when you can't get to the location you wish to record, such as a steep stream bank across the stream, fenced land that you can see from the road, an infestation in the midst of Poison oak, or under tree canopy. Record offset with a distance estimate and the direction in degrees from magnetic north, or just factor it into your error estimate.

The effect of the location error will depend on the scale at which you are collecting GPS information. The larger the area you are mapping, the less significant your location error will be. With maps of very large areas (such as the state), accuracy of each point is less important than in maps of very small areas, where errors in the tens of meters may have a significant impact on the map.

Recording location data

There are two main ways in which your position can be recorded from a recreation-grade GPS receiver. The first is to simply write the coordinates down by hand. When writing down GPS information, carefully avoid transcription errors and be attentive to decimal points and places. The use of UTM coordinates is recommended by some experts as less likely than latitude-longitude to be transcribed incorrectly.

The second (and recommended) way is to use the GPS unit to store your location as a "waypoint" or "landmark" and download the data to your computer upon returning from the field. If paper forms are used for the weed observations, you can write the GPS waypoint number onto the form and link up the information later when you put it all into the spreadsheets, checking the hand-written numbers against the digitally stored ones. Writing the numbers onto paper is a good back-up (what if you drop your GPS in the creek!) Many recreation-grade GPS receivers can store a large number of waypoints that can then be downloaded to a personal computer for use with mapping software. Mapping-grade GPS units, discussed in the following section, allow you to store point, line, and polygon features along with any desired attribute data. Having the capacity to create polygons doesn't mean you have to, however—it can sometimes be very difficult to walk around a stand of weeds in rough terrain.

Review of Selected GPS Units

The following descriptions are not meant to be endorsements of any particular products. The reviews are to give some background on some representative models in order to help you decide which grade of unit will be most suitable for your application.

Recreational-grade GPS units:

The ***Garmin eTrex*** is a small, light GPS unit that is very popular. It has the 12 parallel channel receiver of some of the larger units, but is palm-sized and weighs only 6 ounces. It uses two AA batteries, and can last 18 hours on one set. It can store 500 waypoints and allows creation of continuously recorded "tracks." It is easy to learn to use, and it's rugged enough for the rigors of the field. Several different models of the eTrex are in use by the Team Arundo del Norte mapping project and they report this choice has been fine for their purpose. The eTrex has excellent satellite receiving capability, with performance comparable to much more expensive units and in many cases getting a satellite "lock" much faster. With the cheapest one you must also purchase the data download cable separately. Comes with course roads and stream data for the U.S. This unit, like many other compact handheld GPS receivers, can be augmented with more detailed local data, an antenna, and a cable for connection to a PDA device. Cost: ranges from $110 to $350 depending on features.

The ***GarminGPS III Plus*** is a differential-ready 12 parallel channel receiver that continuously tracks and uses up to twelve satellites to compute and update a position. It has acquisition times of approx. 15

seconds warm and approx. 45 seconds cold. It has a continuous update rate of 1 second. It can store 500 waypoints with symbols and 20 reversible routes, and a track log of 1900 points. It has a built-in detailed base map that covers lakes, rivers, interstates, national/state highways, secondary roads in metro areas, cities, railroads, airports and a detailed exit database for the Federal Highway system). More detailed maps are an option. It has 106 different map datums. It has a NMEA 0183 and RTCM 104 DGPS corrections interface. It has an optional external antenna. Cost: ~$350 for the unit; software and external antenna add $200; and DGPS add $300.

The ***Garmin GPS 12MAP*** (formerly the Garmin 12) combines the enhanced software features of the popular GPS III Plus with the rugged design of the GPS 12. The 12 parallel channel GPS 12MAP boasts the same physical characteristics as Garmin's 12CX (excluding color display), including a rugged, waterproof case, dedicated zoom keys for quick map scaling, and a high-resolution LCD display complete with backlighting. The unit gets up to 36 hours of battery life with four AA batteries and includes the ability to store up to 500 user waypoints. We found this one to work better than the others under canopy. Cost: ~$350.

The ***Rockwell Precision Lightweight GPS Receiver*** (PLGR) is an early vintage GPS unit originally produced for military use. The USDA Natural Resources Conservation Service entered into a memorandum of understanding with the Department of Defense to allow for use of the unit by NRCS employees. Units exist in certain offices statewide and may be utilized for weed mapping project assistance. The PLGR accepts differential GPS signals and is capable of continuously tracking up to five satellites. It has the capacity of storing 999 waypoints and up to 15 routes with 25 legs per route. It is sealed against dust and water up to a depth of one meter. Although the PLGR was never subject to Selective Availability (GPS signal scrambling by the Department of Defense), its accuracy is limited to less than 52 feet (16 meters).

Information is available on setting up and using the PLGR unit, as well as downloading data to a PC for use in GIS software. See the USDA NRCS Nebraska State website website at: <www.ne.nrcs.usda.gov /techresources/www-nri/other/gpis.html>

Mapping-grade GPS:

Trimble's GeoExplorer® 3 system is a high performance 12-channel GPS receiver and handheld GIS data collection and data maintenance system. Its small size, portability and features make the GeoExplorer 3 an ideal tool for creating and maintaining invasive weed infestation spatial databases. As a mapping grade GPS unit, the GeoExplorer 3 system allows the user to accomplish more in the field than is possible with a recreational-grade unit, since you can store point, line, and polygon data. The GPS data collection with full feature and attribute capability allows for data entry into electronic forms in the field. There is no need to carry spare batteries because the internal long-life battery lasts an entire working day and can be recharged overnight. Trimble's GPS Pathfinder® Office software, which comes with the system, aids in data dictionary creation, data processing, and GIS data export and import (it's compatible with a wide variety of GIS software). When coupled with Trimble's Beacon-on-a-Belt (BoB™) differential receiver, you can do differential correction "on the fly," so that your readings in the field are that much more accurate. This enables the user to more precisely relocate existing features by using the graphical navigation and map displays. Cost: ~$4,090.

Hardware for downloading GPS data to your computer

Access to software and hardware for downloading GPS data to your GIS or mapping software on your personal computer gives you an efficient way of collecting, recording, and analyzing large amount of GPS data.

As far as hardware, you need a cable that is compatible with your GPS unit and your personal computer. Usually, GPS units are shipped with a cable that allows downloading; however, other cables may also be compatible with your GPS unit and available for sale on the Internet. You will also need a compatible outlet on your personal computer, usually a USB or other cable-ready port.

Software for downloading GPS data to your computer

You will need software that allows you to transfer the data from the GPS receiver to your computer, and to go the other direction and put waypoints onto a GPS from the computer (a handy way to transfer waypoints between GPS units.) Some units come with such software. You can also use free extensions downloaded from the Internet. The two most common freeware GPS extensions are Garmin.avx and Waypoint+, and are both compatible with ArcView GIS 3.x, and ArcGIS 8. The file you get when you download from the GPS receiver is a simple text file with data in rows, including the coordinate ID number, the X and Y data, date, time, and other collected data such as elevation. These files can be stored together in a folder with other files such as photos when you assemble your data after conducting a survey.

TOPO! software has a built-in menu item for transferring coordinates from Garmin and other GPS units to your computer, as well as

SOFTWARE AVAILABLE ON THE INTERNET FOR DOWNLOADING GPS DATA TO YOUR COMPUTER

Garmin.avx can be found at: <http://arcscripts/esri.com/details.asp?dbid=11515>

Waypoint + can be found at: <www.tapr.org/~kr2z/Waypoint/>

Other resources and discussion about these extensions can be found at:

Remote Sensing Lab AV Garmin & Waypoint+ discussion: <www.r5.fs.fed.us/rsl/gps/garmin.html>

Point Reyes Bird Observatory AV Garmin & Waypoint+ discussion and examples:

<www.prbo.org/tools/GPS/garmindownload.pdf>

transferring them from the computer to the GPS unit after you've made points with your mouse on one of their maps.

3.3 Collecting map data using handheld computers

Personal Digital Assistants—PDAs—and the more capable palm-sized mini-computers can be connected to GPS receivers (recreational or mapping-grade) with special cables, and with appropriate software and some technical know-how can be set up with custom electronic forms to capture the descriptive information that would otherwise be recorded on a paper form or in a data dictionary. The descriptive (attribute) information is stored together with the location data.

Several combinations are in use, such as the Pendragon and Cybertracker software solutions on a Palm OS device. The forms for data capture must be developed on the desktop computer beforehand. A reportedly easy and effective set up can be had with ArcPad software on a Compaq iPaq, attached to a GPS unit. Detailed local GIS data in the form of shapefiles and imagery can be displayed with your current location. Trimble's TerraSync software integrates their GPS equipment with GIS data display and the data dictionary building capabilities of Pathfinder Office for display on a Windows mini-computer such as the Compaq iPaq.

It is even possible to integrate a digital camera with GPS, stamping images with the coordinates at which they are taken. There are many possible combinations of hardware and software, and at this time there is not a single configuration that we can recommend. Fortunately there are likely to be developments in this area that will result in systems that can be used effectively by the weed-mapping community, and in subsequent editions of this handbook we will attempt to share what has been done.

3.4 Managing map data with GIS technology

<u>What is GIS?</u>

There are many definitions of Geographic Information Systems, or GIS. Simply put, a GIS is digital mapping with intelligence. It is a computer technology that brings together all types of information associated with a geographic location for the purposes of querying, analysis, and generation of maps and reports.

A GIS is an organized collection of computer hardware, software, and geographic data designed for assembling, storing, updating, manipulating, analyzing, and displaying data that is identified according to location, or geographically referenced. A GIS is commonly referred to as an integrative technology, allowing analysis of multiple "layers" of spatial information representing various aspects of physical and human geography. In ArcView 3.x these layers are referred to as themes. Some common examples of themes are elevation (i.e. digital elevation models or DEMs), streams, vegetation, roads, soil type, and land ownership. Data recorded with Global Positioning System (GPS) receivers can also be used as GIS themes.

Skills required to learn GIS

GIS is a computer technology. In order to embark upon GIS you will need good basic computer skills and a working understanding of concepts in geography. Fortunately, there are many resources for building these skills (see the Section 4.7), but it takes time and patience. Full-fledged GIS and cartography is a professional career, and organizations planning to incorporate these into their projects will need to consider hiring of dedicated staff. At the same time, GIS software applications are becoming more user-friendly, so simple projects can be accomplished without being a GIS expert. The information that follows is an introduction only; there is no substitute for taking classes, reading books, and talking with experienced users.

Data types

Data for a GIS comes in three basic forms:

Spatial data: Spatial data is made up of points, lines, and polygons and is at the heart of every GIS. Spatial data forms the locations and shapes of map features such as buildings, streets, or cities.

- Points represent anything that can be described as an x,y location on the face of the earth, such as invasive weed locations, homes, utility poles, bridges, and site landmarks.
- Lines represent anything having a length, such as streets, highways, rivers, or invasive weed infestations following a ditch bank.
- Polygons describe anything having boundaries, whether natural, political or administrative, such as the boundaries of countries, states, counties, cities, assessor parcels, national forests, large noxious weed infestations, and wilderness areas.
- Representation is scale dependent. For example, an 8.5”x11” map of all of California would best use points to represent cities. The same sized map of Sacramento County could use polygons.

Tabular data: Tabular data contains the attributes and descriptions for the mapped features. For example, a map of customer locations may be linked to demographic information about those customers. If you have lists, spreadsheets, or databases about information like weed lists, where infestations are located, or others, you can link this information to the data in a GIS.

Image data: Image data is "raster" data (see Section 1.4), including satellite images, aerial photographs, digital photographs, and scanned data (data that's been converted from paper to digital format). Geo-referenced aerial images can be displayed as maps along with vector layers. Images can also be attributes of map features such as photos of the site identified as points in the spatial data. For example, you can create links in your database to photos of an infestation site to other map features so that clicking on the feature would display the image.

In addition, this data can be further classified into two types:

Vector data **-** Discrete features, such as infestation locations and data summarized by area

Raster data **-** Continuous numeric values, such as elevation, and continuous categories, such as vegetation types

<u>Spatial data scale and resolution</u>

Scale is the ratio of the distance measured on a map to that measured on the ground between the same two points. For example a quoted scale of 1:50,000 implies that a distance of 1 cm on the map translates to a distance of 50,000 cm (or 500 meters) on the ground. Often, the difference between large and small map scales is confused. The larger the ratio, the smaller the map scale. Therefore, a map of the world would have a very small scale, whereas a map of a town center will have a large scale.

Resolution is the smallest distance that can be usefully distinguished (resolved) on a map with a given scale, for example on a 1:10,000 scale map the smallest distinguishable distance is 0.5 mm which equates to a distance of 5 meters on the ground.

<u>Spatial Data Accuracy</u>

It is worth noting that the accuracy of a map cannot be 'better' than its resolution, but it can often be much 'worse'. The larger the map scale, the higher the possible resolution. In a GIS where spatial data sets from a range of sources are integrated and the scale is changed by zooming in and out, it is vitally important to be aware of such issues and not to analyze spatial information beyond the resolution of the data source.

Spatial Data Storage

Most GIS software allows the user little (or no) choice on how spatial data, such as Universal Transverse Mercator (UTM) coordinates or decimal degrees, are stored. Users of GIS inevitably find that requirements for data storage expand at least as rapidly as the capacity of available storage devices, so efficient use of available apace is essential. Raster models for GIS data typically require more storage than does vector data, due to the large number of cell values that must be stored. When data is processed it must be read from the storage device and after processing be re-written. Reading and writing data is usually the slowest part of data processing.

Spatial Data Resources

"Base layers," such as roads, waterways, or political boundaries, can be downloaded from the internet, purchased from private vendors, or gathered from local data sharing sources such as the Department of Fish & Game, CalTrans, Department of Water Resources, utility companies, timber companies, US Forest Service, or BLM. The GIS Data Depot, at <www.data.geocomm.com>, has a variety of data layers available at statewide and countywide levels including Digital Elevation Models (DEM), scanned USGS topographic quads or Digital Raster Graphics (DRG), aerial photography or Digital Orthophotos (DOQ/DOQQ).

The California Spatial Information Library (CaSIL) is another good source of spatial data. They also offer satellite imagery or SPOT data for the years 1998 – 2000. The web address for CaSIL is <www.gis.ca.gov>.

Newly acquired data, such as invasive weed locations, are commonly gathered using GPS receivers or created by tracing or "digitizing" locations from "hardcopy" maps. This task can be accomplished on the computer screen or with a digitizing board using the GIS software.

Spatial data input

A GIS must provide methods for inputting geographic (coordinate) and tabular (attribute) data. The more input methods available, the more versatile the GIS. There is no single method of entering the spatial data into a GIS. Rather, there are several, mutually compatible methods that can be used singly or in combination. The choice of data input method is governed largely by the application, the available budget, and the type and the complexity of data being input. There are at least four basic procedures for inputting spatial geographic data into a GIS. These are:

1. Digitizing
2. Automatic scanning

3. Coordinate geometry keyboard entry
4. Conversion of existing digital data

These are discussed in the following sections.

Digitizing

There are 3 basic procedures for digitizing spatial data into a GIS. Note that errors in the original maps (all maps have them) will be transferred—and likely magnified—when digitized into a GIS.

Manual digitizing: While considerable work has been done with newer technologies, the overwhelming majority of GIS spatial data entry is done by manual digitizing. A digitizer is an electronic device consisting of a special table upon which the map or drawing is placed. The user traces the spatial features with a hand-held magnetic pen, mouse or cursor whose position is sensed by the table. While tracing the features the coordinates of selected points, e.g. vertices, are sent to the computer and stored. Digitizing tables electronically encode cursor positions with a precision of fractions of a millimeter; these can be converted immediately into map coordinates. The coordinates are recorded in a user-defined coordinate system or map projection. The cursor typically has a crosshair for precise positioning and a 16-button keypad for entering attributes and interacting with the control program. All points that are recorded are registered against positional control points, which are usually the map corners that are keyed in by the user at the beginning of the digitizing session. The ability to adjust or transform data during digitizing from one projection to another is a desirable function of the GIS software.

"Heads-up" digitizing: This method uses a scanned map, remote sensing image, digital orthophoto, digital raster graphic, or some reference layer that is shown on the computer screen and the operator traces over the desired features with the mouse. This procedure is OK for small projects or "touch-up" editing, but too tedious and error-prone for production work.

"Live" digitizing with GPS: This procedure is performed using a GPS receiver to record known infestation locations in the field. This is easily accomplished for point locations with all GPS receivers. Linear and area infestations can be recorded with mapping-grade GPS units that are capable of storing line and polygon information. However, with GPS units that are only capable of recording point locations, multiple points should be recorded at various positions along the infestation border. Once these points are incorporated into the GIS, a conversion or "heads-up" digitizing can be performed to connect the series of points into a polygon.

Automatic Scanning

Flatbed scanners or drum scanners can be used, but high-precision devices are very expensive. The output from a scanner is a digital image—the line work needs to be extracted from the image by software. Post-scanning line extraction and editing is at best a semi-automatic process, which still requires considerable user intervention to build clean topology. Sometimes hard copy data may not be in a form that is viable for effective scanning, which results in poor quality maps. Maps are frequently re-drafted and simplified before scanning which, may not be cost-effective for maps with sparse line work. Many times the scanner may be unable to distinguish between closely spaced features. Scanners work best when the information on a map is kept very clean, very simple, and uncluttered with graphic symbology. For most maps, scanning is much more expensive than manual digitizing. On the other hand, it is claimed that scanning is 5 to 10 times faster than manual digitizing, even if the map needs to be re-drafted beforehand.

Coordinate geometry keyboard entry

Coordinate geometry (COGO) procedures are used to enter land record information requiring a very high level of precision. This information is in the form of "X distance in direction Y from the last point." Actual survey measurements are entered manually into the GIS database. This can be more than 20 times more expensive than manual digitizing. COGO is mainly used by surveyors and engineers; planners and resource managers rarely need the extra precision involved.

Conversion of existing digital spatial data

There are many existing digital spatial data sets that may contain some or all of the data you require. The problem is that the data may not be exactly what you need or be in a data format that is compatible to your system. Most modern GIS systems, including ArcView, provide a wide range of data translators to convert from foreign data formats to the native format of the system you are using. Most systems take a self-centered approach: they provide many more functions for importing data than for exporting data. The trend in GIS is to leave data in their native formats and convert "on the fly."

Some common spatial data formats include:

Digital Line Graph (DLG): This ASCII format is used by the United States Geological Survey (USGS) as a distribution standard and consequently is well utilized in the United States. Most software vendors provide two-way conversion to DLG.

Drawing Exchange Format (DXF): This ASCII format is used primarily to convert to/from the AutoCAD drawing format and is a standard in the engineering discipline. Most GIS software vendors provide a DXF translator.

ARC/INFO GENERATE (Graphic Exchange Format): This is a generic ASCII format for spatial data used by the ARC/INFO software to accommodate generic spatial data.

ARC/INFO EXPORT (.e00): This is an exchange format that includes both graphic and attribute data. This format is intended for transferring ARC/INFO data from one hardware platform, or site, to another. It is also often used for archiving ARC/INFO data. This is not a published data format, however some GIS and desktop-mapping vendors provide translators. EXPORT format can come in uncompressed, partially compressed, or fully compressed format.

<u>Tabular data input</u>

Attribute data has an even wider variety of data sources. Any textual or tabular data that can be referenced to a geographic feature can be input into a GIS. Tabular data for use in a GIS can be purchased already packaged with spatial data or it can be found in your own organization. If you have lists, spreadsheets, or databases about information like noxious weed lists, where weed management areas are located, or others, you can use this information in a GIS. If you have the correct spatial data, the GIS can link your tabular data with the spatial data. For example, you can link treatment information with infestation areas, allowing you to map treatment by weed species. There are several ways to input tabular data into your GIS.

- Type attribute data straight into ArcView
- Load tabular data from files
- Load tabular data from databases using ArcView's SQL connection capability
- Join tabular data to features shown on a map

Typing attribute data straight into ArcView: You can edit the attribute table of a shapefile or a table whose source data is a dBase format. An easy way to get your data into ArcView is to type it straight into the attribute table belonging to the appropriate theme. You will need to choose 'Start Editing' from the table menu to begin this process.

Loading tabular data from files: Tables can be added to ArcView from .dbf files or from ASCII text files with the .txt extension. The .dbf files can be created by a number of Windows-based programs. Text files can be created with any electronic editor. Columns must be comma or tab delimited. The first row should contain the column labels and these must be comma or tab delimited.

Loading tabular data from databases using ArcView's SQL connection capability: You can access data in external databases using ArcView's SQL connection feature. This feature allows you to query a database using SQL and store the returned records in an ArcView table. The ArcView tables cannot be used to modify the database directly, but you can execute data manipulation and data definition SQL statements with the SQL connection by using Avenue. ArcView uses Open Database Connectivity (ODBC) to connect to external databases on PC platforms. To connect to SQL databases, the Microsoft Windows versions of ArcView uses Microsoft's ODBC standard. ODBC is Microsoft's open interface for accessing data in a heterogeneous environment of relational and non-relational database management systems. To use your database with ArcView, install an ODBC driver for your database. Then use the ODBC Administrator to configure a data source for your database. ArcView should work with any database for which you have an ODBC driver and any necessary database client software.

Joining or linking tabular data to features shown on a map: Joining an external database without location information to an ArcView table with location information can be very beneficial. When two databases have a common field and describe the same features, the table that does not contain location information can be joined to the table with location information. Once this is done, features can be classified based on the external database. You can also add a link between two tables when two common fields are chosen. Links can be added when record relationship is one-to-many or one-to-one. Fields are not appended to the destination table. Selections display the "linked" information.

Spatial data processing

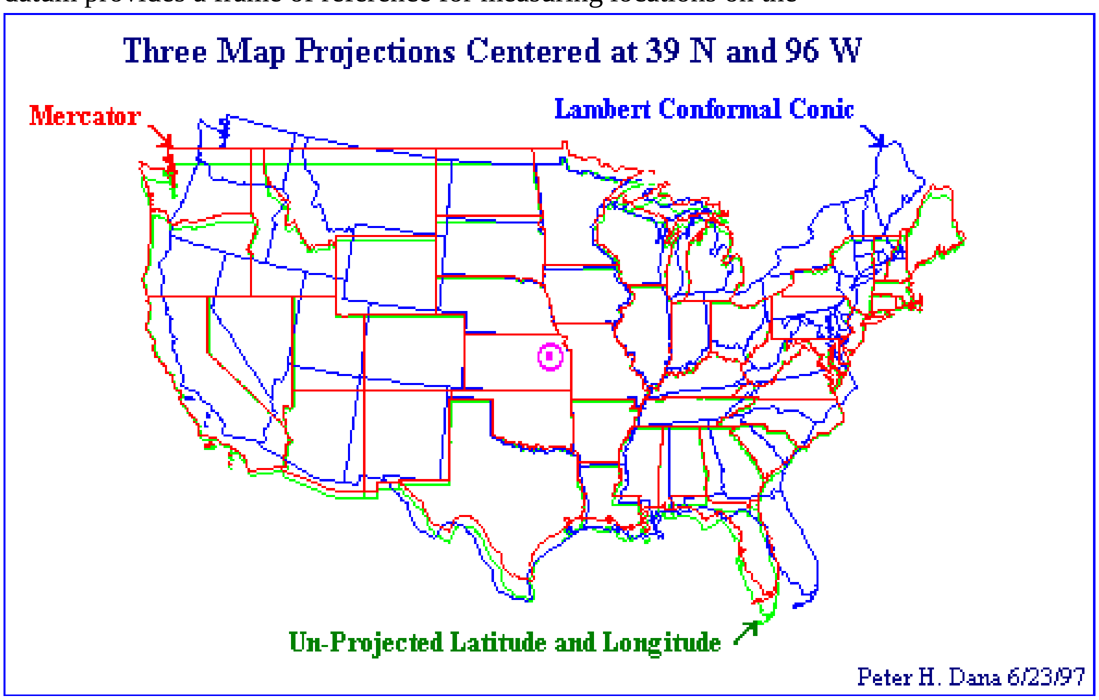
The most important issue facing GIS users is maintaining a common projection throughout your dataset. A decision will need to be made as to which projection and datum will be used throughout your GIS before you begin. Understanding projections and coordinate systems and their effects is fundamental to working with GIS data. Particularly on maps covering large areas, the curvature of the earth must be taken into account in order to represent the areas on a flat sheet of paper or computer screen. When data is acquired from different sources, the input data is often in different projections. As such, transformation of one or all maps to make coordinates compatible is required. Remember, however, that even if the coordinate systems and projections are the same, if the data is in a different datum or was projected under different ellipsoids, identical objects will not line-up.

Projection definition

(Section 1.2 discusses projections and datums in more detail—this section is a refresher.) .Paper maps are flat representations of curved surfaces. The transforming of three-dimensional space onto a two-dimensional map is called projection. There are many mathematical expressions used for projection formulas. They all seek to convert data from a geographical location on a sphere to a location on a flat surface. This process unavoidably distorts at least one of four things (and often times more than one of these): shape, area, distance, and direction. Briefly, "conformal" maps preserve local shape, "equal-area" or equivalent maps retain all areas at the same scale, "equidistant" maps maintain certain distances, and "true-direction" maps express certain accurate directions. The figure below shows how the U.S. map differs when different projections are used.

Datum definition

There are many spheroids representing the shape of the earth. A datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the



surface of the earth. It defines the origin and orientation of lines of latitude and longitude. A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the origin point of the datum and all other points are calculated from it. The coordinate system origin of a local datum is not the center of the earth. Because the earth is a spheroid, a local datum is limited in accuracy to a finite area surrounding its point of origin and an earth-centered datum is potentially more accurate over a larger area. The two datums used almost exclusively in North America are NAD27 and NAD83. NAD83 is more accurate and should be the datum of choice.

Re-projecting data

You will oftentimes have to re-project data from other sources to match the projection you have decided on for keeping your data. For instance, the State of California uses Teale Albers projection (described in Section 1.2) for most statewide data, but most others do not use this projection, so adding state data to your own will require re-projecting the added data.

Many GIS software packages, such as ArcView 3.x and ArcGIS 8.x, have re-projection utilities as part of the suite of tools or extensions. ArcView 3.x has its extension, "ArcView Projection Utility," which presents a user-friendly interface that steps you through the process. With ArcGIS 8.x, the tool is part of ArcToolbox.

When re-projecting data, the user enters both the input and the output data projections. It is important to note that if the input and output projections use different datums, a geographic transformation *must* be used in the re-projection to account for any shifts between datums. For example, if the input data projection is in NAD 1927 datum and you are re-projecting to a projection that uses NAD 1983 datum, you would use NADCON geographic transformation. Re-projection tools, such as those in ArcView 3.x and ArcGIS 8.x, have windows or menus in which you can choose the geographic transformation.

With many software packages, you can import your output projection file. This is especially helpful for the Teale Albers projection used by much of California, as importing the projection saves time and effort in comparison to entering each parameter of this uncommon projection (outside of California) by hand. You can find the projection file, or .prj file, at <www.cdpr.ca.gov/docs/county/pumpdvlp/pumpmenu.htm>. Right-click on "Teale Albers .prj file for ArcView Projection Utility" and save it to your computer. The correct parameters for the Teale

Albers projection are embedded in that file, and are automatically entered as the output projection (if you are re-projecting to Teale Albers) when you import the file into the re-projection program or extension.

More information on the NADCON geographic transformation can be found at <ftp://ftp.ngs.noaa.gov/pub/pcsoft/nadcon/Readme.htm>, and a step-by-step guide to using NADCON with the ArcView Projection Utility can be found at <www.cdpr.ca.gov/docs/county/pumpdvlp/devgrp/prjctdta/pres0401.htm>. Please note that there are many different ways to re-project data, depending on your software and data.

General GIS spatial functions

General spatial functions performed within a GIS include: querying spatial data (e.g. when you want to know what vegetation is dominant in an area, or if you want to find out if a feature is within another feature, like whether a weed site is within a particular county); classifying data (e.g. calling all Yellow starthistle sites "class A noxious weeds"); and measurement of all lines and areas.

"Buffers," or "proximity routines," are very useful spatial routines. You can think of a buffer as a fixed or variable distance width away from a point, line, or polygon feature (e.g. within 100m of a stream). There are other spatial functions that are very useful and easily performed in GIS software. These are all related to "overlay" operations. Boolean operations (such as intersections, unions, etc.) can be done within a GIS. One can also treat maps as layers, and use the layers as data in mathematical functions. In other words, you can find the addition of several data layers, or subtract one layer from another to find change between the two. Site suitability modeling, where you try to find the most appropriate location for a feature (e.g. a waste facility or a campground) based on a series of input layers, is really a combination of these overlay operations. You might say the best location for a campsite is within a certain distance from a stream, and in a certain forest type, and on a certain slope. By giving each layer (distance from streams, vegetation classes, and slope) a score based on its suitability, the best location will be the location with the highest score overall.

Topographic functions

Topographic functions are those GIS functions designed to work with 3-dimensional data (like a Digital Elevation Model or DEM). From a DEM one can derive slope and aspect. One can also think of these functions as useful for smoothing out raster data with many variations, or enhancing those variations. These latter two processes are called filtering. When you have only point data, for example samples of the elevation across an area, you can create a continuous surface from those points by a process called interpolation.

GIS spatial analysis

Spatial analysis, or spatial statistics, is a class of statistics that consider the location of data points, and importantly the distance between data points, as important factors in statistical analysis. In other words, the pattern of your samples is just as important as the data gathered at the samples. In fact, the pattern can indicate something about the forces at work structuring what you are looking at. For vegetation, patterns of one species might indicate that it primarily colonizes from seed distributed close by, or that it grows only on cooler slopes.

Display of spatial data

Spatial data can be displayed in static map form, and this traditional cartography has been made simpler with GIS software such as ArcView. Advances in Internet technology now allow for multiple new ways of displaying spatial data. Animations and WebGIS are two new methods used to display spatial data.

Cartography can be an easily overlooked part of the GIS process. Maps have incredible power to communicate quickly and succinctly, if they are designed well. (Section 3.6 briefly discusses this process.) We encourage you to not think of the map as a cast-off of the GIS process, but in and of itself an important, powerful communication tool that requires time and care in its creation.

WebGIS

GIS delivered on the web is a fascinating new arena for GIS. There are software packages now that allow users to perform simple GIS tasks over the web without having GIS software and data resident on their own computers. One of the most popular is ESRI's ArcIMS, which allows users to view, query, and in some cases analyze data on distant servers. To view some examples of WebGIS, see <www.esri.com/software/ internetmaps/visit_sites.html>.

The Internet has also become a useful and highly visible repository for maps created through GIS analyses.

Animated data

Animated GIS is a new and exciting arena for cartography, allowing processes to be seen through time. Animation is usually done by creating a series of static maps, and then viewing them in sequence. A good example of this is at: <http://hilda.espm.berkeley.edu/SODmonitoring/whereisSOD/movie/>.

3.5 Producing maps from data

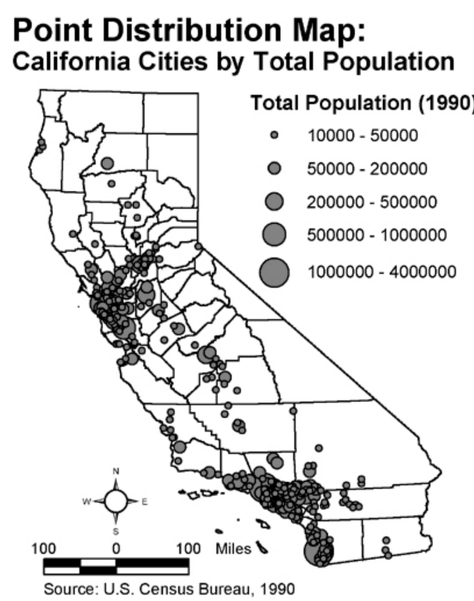
Spatial data in the form of points, lines and polygons (vector data) and continuous coverage (raster data, i.e. elevation data) can be made into maps that easily communicate your message. (See sections 1.3 and 1.4 to read more about these data types). Maps come in many different formats and styles, but there are some basic rules that can be articulated here. Much of this information comes from John Campbell's Introductory Cartography.

Elements of a Map

Most maps include some of the following elements in addition to mapped data:

- Neatline or border: this defines the area of the figure. Often this is left off modern maps, but it can frame the figure nicely;
- Legend and title: a legend should fully identify any symbols on the map that require explanation;
- Graphic scale: depicting the scale of the mapped data;
- Graticule or grid marks: these display the latitude and longitude of an area, or other coordinate system;
- North arrow;
- A map inset: this shows where the main map area is located in the world.

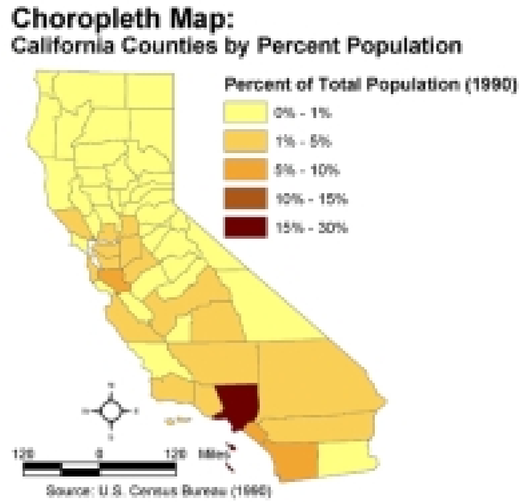
GIS packages like ArcView provide the means to create all of these with great flexibility.



Types of Maps

Point Distribution Maps:

Simple point data can be used to create point maps. Point maps can also be more complicated than a distribution of points; these points can be scaled to the size of the mapped variable. The map at right shows such a mapped distribution of point data – population in cities. In the case of weed mapping, each point could represent the location of a particular weed found in an area, and the size of the point could indicate the size of the plant, or the number of seed pods visible on the plant.



Choropleth maps:

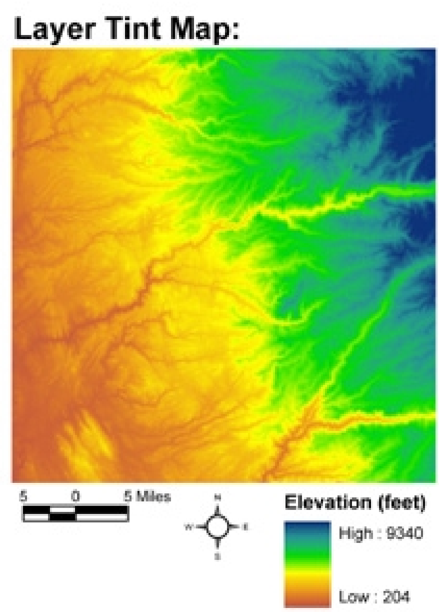
Choropleth maps use existing regions, such as counties, or census tracts, to map the amount of a variable within that region. For example, you could map the number of weed mappers per county in California using a choropleth map. These maps are striking, and convey complex information quickly and clearly, provided you use colors, shades or patterns that are distinct from each other. The map to the left shows a typical use of a choropleth map: population by county.

Surface Maps – Contours:

Continuous data, such as elevation, can be mapped in a number of ways. A common surface map is the contour maps - seen in the USGS 7.5-minute topographic quadrangle series. Contours, or isolines, are lines that join points of equal value. Elevation data are not the only kind of continuous data that can be mapped with contours. Population density, for example, can be mapped with contours. These are commonly seen maps, and easy to interpret.

Surface Maps – Layer Tints:

This type of map takes the contour map one step further and adds color to the mix. On an elevation map, the area between two isolines, or contours can be given a color. When a color ramp that progresses from light to dark, or progresses through the color wheel is used, it creates a pleasing impression of elevation change. GIS software packages now allow for sophisticated color ramping such as that seen in the map to the right. The colors blend from color to color in a visually pleasing manner.



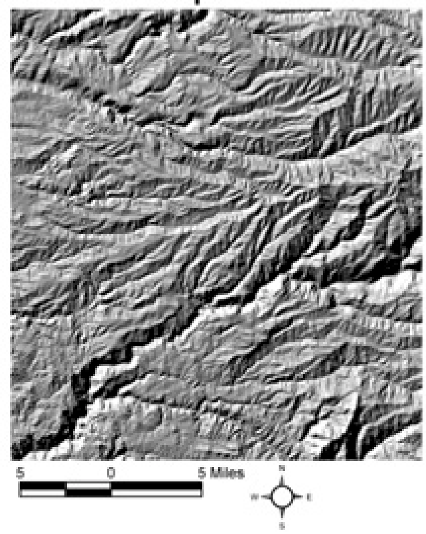
Surface Maps – Hill Shading:

GIS software packages allow for another mechanism for creating the impression of a 3-dimnsional surface on a 2-dimensional sheet of paper. Hill shading is a method of creating artificial illumination on the surface, creating shadows and illuminating surfaces as might be seen in the real world. This gives the sense of topographic relief clearly.

Map Design

When creating a map, it is useful to consider balance, legibility, contrast and the selection of appropriate pattern and color in the creation process. The goal of map making is to create a product that is informative, but also pleasing to the eye. So try different variations of placement of map elements to create a pleasing, balanced map, as well as different fonts and sizes in typography to increase legibility. Make sure your featured area is highlighted from the background if necessary (you can use color or gray shading, pattern, or varying line weight to do this). Get a sense of the colors you are using, are they too similar to distinguish between? Do they clash? It is always a good idea to try several different color combinations.

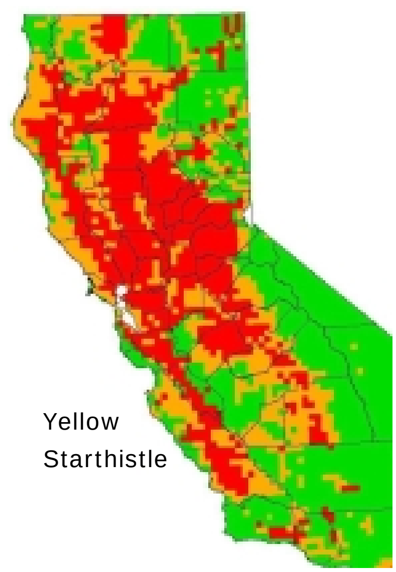
Hillshade Map:



Color Use in Maps

Color use in maps has the ability to dramatically heighten your message, but it can also provide a distraction for the viewer when miss-used. Much theory has been developed that can aid a cartographer in choosing colors in maps. One of the best tutorials is: <www.personal.psu.edu/faculty/c/a/cab38/ColorBrewerBeta2.html>, where you can chose different color schemes, and see how they change your perception of the results. You should also be aware that many colors are not perceived equally by all people, and some should be avoided.

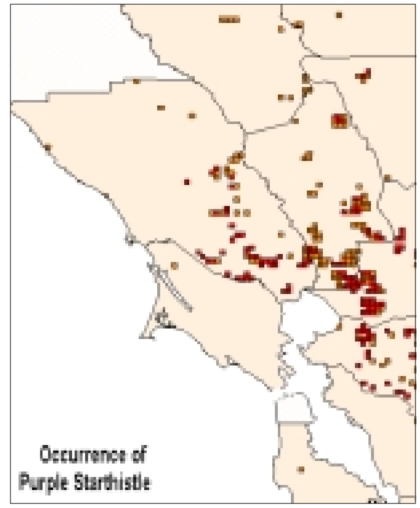
3.6 Setting strategy and monitoring progress with map data



California contains a total of 1,200 non-native naturalized plants. Not all of these "weeds" are equal in their abundance, destructiveness or rapidity of spread. Clearly resource constraints keep regional weed-mapping programs from mapping all weeds at a high level of detail. Programs need to prioritize, or "triage," which species are mapped and to what level of detail they are mapped. Here are some principles to help design the best strategy for your program.

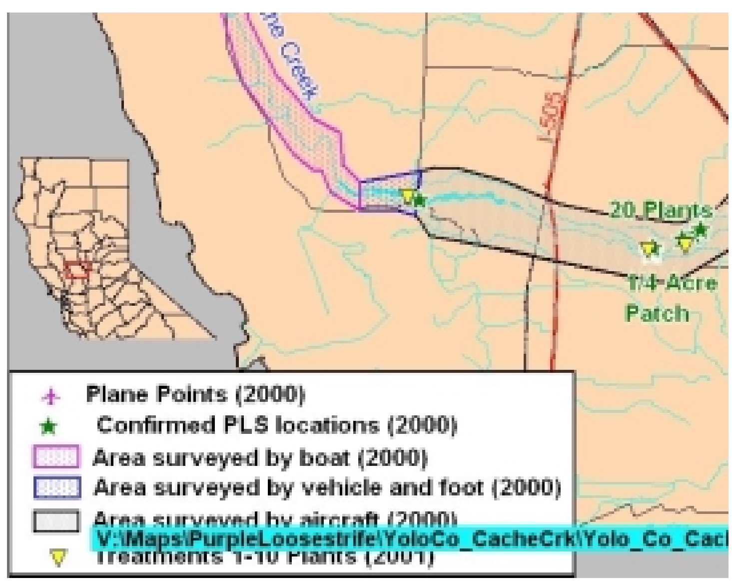
In the early stages of an inventory program, it can be very useful to start with a grid survey of presence/absence based on assessments by knowledgeable people. The grid can be based on Townships or square mile sections (see maps at right), or other useful grids, such as USGS 7.5 topo quadrangles ("quad maps") or quarter-quads. Often this survey can be initiated without any fieldwork or equipment, and can then be improved and validated with targeted field surveys.

Focus on why you are mapping: Predominantly, mapping is done as a prelude or companion to a weed control or eradication program. A strategic and long-term approach to noxious and invasive weed control is based on a solid knowledge of the countywide distribution of the weeds. The choice of control objective (i.e. eradication, suppression, or containment) and control technique will depend on how the weed is spread over the landscape. Because funding for cooperative weed control is very tight, resources must be allocated in a highly strategic fashion. Infestations which are pioneers in an otherwise un-infested area are typically prioritized for aggressive eradication, whereas control projects in heavily infested areas need to have clear long-term justifications and strategies.



Remember that you can map at different resolutions within a region for the same species as well as different species – one size does not fit all: The weed mapping strategy itself should be tied to the average infestation level of the region and the management goals for the populations in the region. In areas where weeds are very heavy it is not necessary or feasible to do fine grained, intensive mapping. Mapping these weeds at the section or even township level can provide most of the information that is necessary for regional prioritizing. Where the weeds are in small, localized populations, more accurate locality information is needed for eradication efforts. Mapping weeds intensively and accurately at the edge of a containment zone is also critical to succeeding at stopping spread. These different styles or modes of mapping can be combined on the same maps. For example, where a weed is heavy but patchy in a region a section grid could represent the distribution of hotspots and light areas. As you move toward an un-infested part of the region a higher emphasis could be placed on capturing center points of infestations. Any populations that are smaller pioneers or outliers in an otherwise un-infested area deserve the most intensive mapping effort because these should be targeted for long-term eradication efforts.

Start with simple overview mapping -- grids and points are most efficient for assessing weeds over landscapes larger than a few square miles: Mapping does not need to be done by trained professionals with expensive GPS units. With proper identification and training most individuals, including volunteers, can map weeds either with inexpensive GPS or paper maps. Using point data to document the approximate position of discreet weed locations is probably the most useful way to depict weed distributions across a landscape. Actual perimeter-polygons of moderately sized infestations will not show up at this scale. The need for mapping perimeter-polygons is most

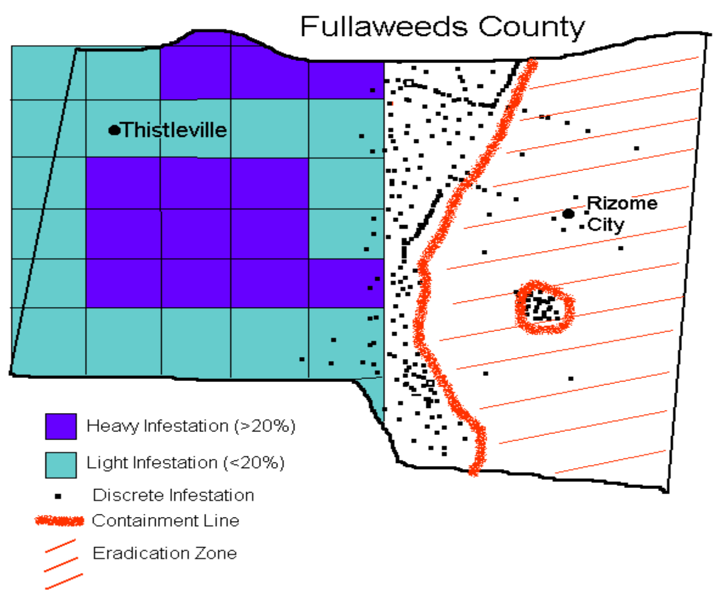


appropriate when close-up resolution is used in mapmaking and the populations have a control program being implemented. Often these detailed maps are useful in project planning.

An Example

The Fullaweeds County Weed Management Area (FWMA) was particularly interested in stopping the spread of purple razor weed (PRW). At a meeting, WMA members spread a map of the county out on the table. The map had a 36 square mile township grid on it. They decided to create three categories of infestation level: heavy, light, and none. Some members present at the meeting gave the townships *tentative* ratings.

The map was then reproduced and distributed to 75 people in the county for them to mark infestations. After two months the mapping committee compiled the returned into one map. The FWMA studied the map and saw a pattern in the distribution of PRW—it was heavy in the west and transitioned to very light to non-existent in the east. They put together a survey team that intensively covered what seemed to be the transition zone where the infestation was between light and none, taking GPS points at the center of any PRW infestations they found. They also did extensive outreach through the newspapers, fliers, and groups to locate isolated populations in the un-infested zones. Based on these surveys and a number of assessment meetings with stakeholders, they created the map at right, which divided the county into management zones. This map will guide the group's treatment strategy for PRW.



SECTION 4: RESOURCE APPENDICES

SECTION CONTENTS:

These resource appendices contain a variety of materials, ranging from generic forms that you may modify for use in you r own program, to case studies of projects undertaken by others. There are also two files on the accompanying diskette. One corresponds to the materials in Sections 4.1 and the other is a simple Excel workbook formatted for keeping track of project materials.

4.1 CDFA Weed Observation and Monitoring Form

Bold line items (also asterisked) are required; other lines are optional.

METADATA	
Collection date (mm/dd/yyyy)*	
Observer name*	
Observer contact information*	Address: City: State: Zip:
	Phone:
	Email:
Source of the data*	Organization name or WMA Code:
Hand-annotated map ID	
SITE DESCRIPTION	
Site name or ID*	
Site address or other description	
State*	
County*	
National ownership*	
Local ownership	Landowner name:
Quad name	
HUC number	
Land use type	Ag Rangeland Rural Res. Urban Indust/Comm. Other
Invaded vegetation type	Forest Woodland Chap/Scrub Grass Herb Aquatic-Fr Aquatic-Sa Marine
Gross Area	Area: sq. ft. sq. m sq. mi. acres ha
Disturbances & impacts	
Associated species	
WEED DESCRIPTION	
Weed genus and species*	
Weed common name(s)	
Presence or Absence*	**P** **A**
Infested area*	Area: sq. ft. sq. meters sq. mi. acres ha
Canopy Cover*	Choose one: <1% 1-5% 5-25% 25-50% 50-75% 75-95% 95-100%
Appearance/phenology	Circle any: germ'g./early growth new growth flowering seeding senesc. dead
Distribution pattern	Circle any: clumpy scattered patchy scattered even linear
Photo documentation	(Use table on back to log photos)
Weed Location	
Geo Feature type*	Circle one: Point Polygon Line
Geographic location*	GPS waypoint or feature ID:
	Coords. (if point): X: Y:
Coordinate system*	UTM Zone: Lat/Long dec. degs Other (specify):
Datum*	WGS 84/NAD83 Other (specify):
Location offset	Distance: feet meters Bearing/direction:
Location data accuracy*	Choose one: <1m 1-5m 5-15m 15-100m 100m-1km 1km-10km >10km
Locality description	
Distance to water	Est'ed distance: Horiz or Vert? Units:

Photo Log					
Photo #	GPS waypoint or feature #	X Coordinate	Y Coordinate	Bearing or Direction	Feature/Notes

Notes

Attach this form to hand-drawn map and write the date, observer name, and the site and feature numbers on the map for easy cross-referencing.

4.2 A Comparison of the NAWMA and CDFA Data Standards

The left side of this table lists the specific data laid out in the weed mapping standards developed by the North American Weed Managers Association. Where the NAWMA side of the table is blank, it reflects a category added to the draft CDFA standards that is not in the NAWMA standard. When content a field states “pick from list,” refer to the sample data form in Section 4.1 for appropriate listings for that field.

NAWMA Fields			Draft CDFA Fields		
Field Name	**REQ/ NR**	**Content**	**Field Name**	**REQ/ NR**	**Content**
METADATA					
Collection Date	REQ	yyyymmdd	Collection date	**REQ**	mm/dd/yyyy
Examiner	NR	Name of examiner	Observer name	**REQ**	Name of surveyor
			Observer contact info	**REQ**	Address, Phone, Email
Source of the Data	REQ	Codes from NAWMA	Source of the data	**REQ**	Organization name and/or WMA Code
SITE INFORMATION					
			Site name or ID	**REQ**	A local name for the site, or a unique number or code assigned to help keep track of maps, photos, and data.
			Site address or other description	NR	Text description of site locality useful for returning at a later date.
Gross Area And Unit of Measure	NR	# acres/hectares	Gross area and Unit of measure	NR	Estimated area of the general area containing the infestation; this can be used instead of "Infested Area" for large, widely dispersed infestations
Country	REQ	Codes from NAWMA	Country	AUTO	USA implied unless otherwise stated
State or Province	REQ	Codes from NAWMA	State	**REQ**	The state where the survey was done
County_Muncipality	REQ	FIPS codes	County	**REQ**	FIPS, state code, or county name
National Ownership	REQ	Codes from NAWMA	National Ownership	**REQ**	Use codes from NAWMA Appendix C
Local Ownership	NR	Local code	Local Ownership	NR	Name and contact info of property owner.
Quad Number	NR	Quad code from index map	Quad Number	NR	Quad code from index map
Quad Name	NR	Quad name from map	Quad Name	NR	Quad name from map
HUC_ Number	REQ	HUC code	HUC_ Number	NR	Look up, extrapolate from GIS
			Land Use Type	NR	Pick from list
			Invaded Vegetation Type	NR	Pick from list
			Disturbances and Impacts	NR	Pick from list
			Associated Species	NR	Scientific names
			Photo Documentation	NR	Coords, bearing, and name of feature

WEED OBSERVATION					
Weed Identification					
Genus and Species	REQ	Genus, species PLANTS codes	Weed Genus and Species	**REQ**	Genus and species names from CDFA list
Common name	NR	common name	Weed Common name	NR	Common name or names
Intra specific and Authority	NR	PLANTS codes	Intra specific and Authority	NR	Comes with the ITIS or PLANTS codes
Plant Code	NR	PLANTS or any other codes	Plant Code	NR	ITIS or PLANTS code
Weed Description					
			Presence or Absence	**REQ**	P or A (implied as presence for most data)
Infested Area and Unit of Measure	REQ	# acres/hectares and units	Infested Area and Unit of Measure	**REQ**	Estimated area of the infestation, with units
Canopy Cover	REQ	%	Canopy Cover	**REQ**	% (pick from Daubenmire classes or give a percent)
			Appearance/Phenology	NR	Pick from list
			Distribution pattern	NR	Pick from list
			Photo Documentation	NR	Coords, bearing in degrees off mag. north or just a direction, and name of feature
Weed Location					
Location Information	REQ	One of 4: STR, LL, M&B, UTM	Geographic Location	**REQ**	Feature ID and type (point, polygon, or line), coord system, datum, and feature name
			Location Offset	NR	Direction and bearing to weed location
			Location Accuracy	**REQ**	<1m, 5- 15 meters, 15-100 meters, 100 meters-1 km, 1 km-10 km, > 10 km, Not Available
			Locality Description	NR	Text description of weed locality
			Distance to water	NR	Distance, horiz or vert, and units

4.3 Summary of Minimum Requirements for Weed Mapping

This table lists all of the required fields of data that need to be taken when weed mapping. It describes how to take this data using three different techniques: hand-mapping, using a GPS and writing coordinates on paper, and using a GPS that can store features in memory.

			--------------*To be done in the field*-----------------				
METHOD	**How to reference between materials**	**Collection Date**	**Observer name**	***Genus & species***	**Site name or ID**	**Weed Presence/Absence**	**Infested Area or Gross Area**
Hand-mapping with paper form	Write a map number on both the map and the form with corresponding data. If there are multiple observations drawn on one map associate these by the feature IDs.	Write on both map and form as mmddyyyy	Full name, write on map and form.	Write on form. Use CalFlora or ITIS for current usages.	Write on both map and form.	Write on both map and form, or just "Absence" or the Canopy Cover does the job.	Indicate Gross Area and/or estimate Infested Area on form and draw polygons when there are good reference features on map, or use point symbols from section 4.1.
GPS with paper form. Hand-mapping may also accompany this method.	Map numbers, date, and observer name on all hard-copy items. GPS data file will have the date, store in a folder with other digital items (like photos) named with the site name and date.	Write on form: mmddyyyy	Full name, write on form	see above	Write on form, and also on map if hand-mapping	See above	Numeric area with a separate line or pick list for units
Datalogger or electronic form (with or without GPS) Create form or data dictionary using these guidelines. Hand-mapping and paper forms may accompany**.**	Depending on your method, you'll end up with geographic and attribute data together in a database or a file. Put referencing info on any hard-copy materials you also use.	If using GPS, the date is stored automatically with each observation	Pick list can be made for regular users	Can create a picklist from CalFlora's or CalEPPC list, or assign beforehand if mapping a single species.	Assign an alpha-numerical ID in the electronic form	See canopy cover	Numeric entry with a separate line or pick list for units

					---*Can be done in office*---			
Canopy Cover	**Local Ownership**	**Nat'l ownership**	**Geographic Location**	**Location Accuracy and any Offset**	**Observer contact info**	**Source of Data**	**HUC_Number**	**County**
Note the % cover or use cover classes in Section 4.2	Write name of property owner on form	NAWMA Appendix C codes	Indicate on map with a Feature ID # that you also write onto the form	Write onto form	Can reference in a separate table in your Excel spreadsheet, check the records you have and update if necessary	Agency or organization that collected the data. Can use WMA code or write full organization name into form	For aquatic plants, can use GIS to get HUC code for stream or river.	Use FIPS codes or full county name
Note the % cover (25%= 0.25) or use a pick list of cover classes in Section 4 2.0	See above	See above	Indicate on map if hand-mapping, and put the feature ID (waypoint #) from the GPS on the map	Write onto form	See above	See above	See above	See above
Make a pick-list that has the choices "Absent" and the cover classes	Create picklist from NAWMA Appendix C	Create a picklist	Location data can be gathered electronically on a GPS unit. If you are also using paper forms and/or maps, put the GPS waypoint # or hand-mapped feature # onto these materials	Log into electronic form	Can be referenced in a separate table in the database and updated when necessary	Can make an automatic part of the electronic form	See above	Can log into data after download

4.4 FIPS Codes for California Counties

These are the common codes used to refer to California counties.

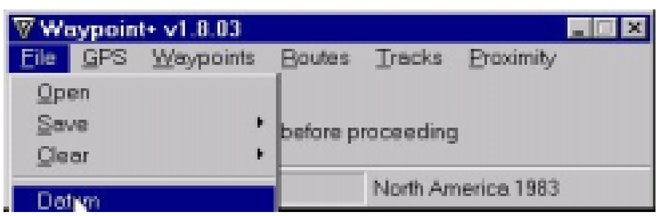
County	FIPS	Cty
Alameda	06001	1
Alpine	06003	2
Amador	06005	3
Butte	06007	4
Calaveras	06009	5
Colusa	06011	6
Contra Costa	06013	7
Del Norte	06015	8
El Dorado	06017	9
Fresno	06019	10
Glenn	06021	11
Humboldt	06023	12
Imperial	06025	13
Inyo	06027	14
Kern	06029	15
Kings	06031	16
Lake	06033	17
Lassen	06035	18
Los Angeles	06037	19
Madera	06039	20
Marin	06041	21
Mariposa	06043	22
Mendocino	06045	23
Merced	06047	24
Modoc	06049	25
Mono	06051	26
Monterey	06053	27
Napa	06055	28
Nevada	06057	29
Orange	06059	30
Placer	06061	31
Plumas	06063	32
Riverside	06065	33
Sacramento	06067	34
San Benito	06069	35
San Bernardino	06071	36
San Diego	06073	37
San Francisco	06075	38
San Joaquin	06077	39
San Luis Obispo	06079	40
San Mateo	06081	41
Santa Barbara	06083	42
Santa Clara	06085	43
Santa Cruz	06087	44
Shasta	06089	45
Sierra	06091	46
Siskiyou	06093	47
Solano	06095	48
Sonoma	06097	49
Stanislaus	06099	50
Sutter	06101	51
Tehama	06103	52
Trinity	06105	53
Tulare	06107	54
Tuolumne	06109	55
Ventura	06111	56
Yolo	06113	57
Yuba	06115	58

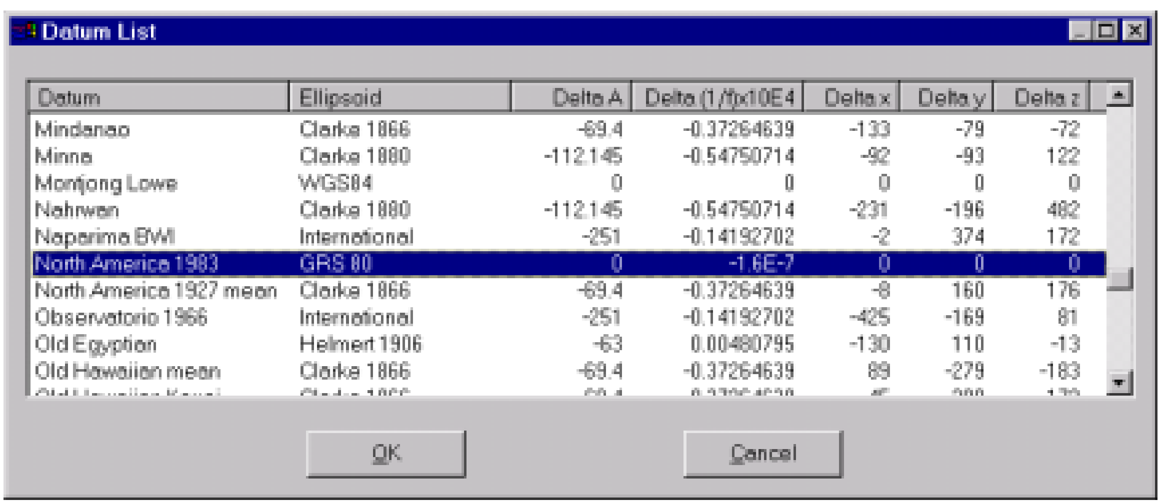
4.5 Creating an ArcView Shapefile from Garmin GPS Data

This section describes the process of converting data from a recreation-grade into a shapefile format that can be used in an ArcView GIS setting. The first steps described below help you use Waypoints Plus to download GPS data from a Garmin unit. If you are using a different brand of recreation-grade GPS unit, download your data using the download tool associated with your unit, and skip to Step 6. Waypoint Plus can be found at <www.tapr.org/~kr2z/Waypoint/>. Garmin.avx can be found at: <http://arcscripts/esri.com/details.asp?dbid=11515>.

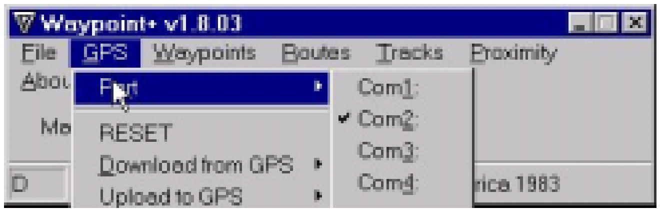
Step 1. Turn off the GPS unit and connect it to the computer's serial port (probably COM1) using the PC interface cable.

Step 2. Launch Waypoints Plus and go to File-Configuration-Modes. Set the coordinates to Decimal Degrees and the units to whatever you need. Go to the File-Datum menu and select NAD83. (You can choose a different datum if you know what you need—Waypoints Plus takes the data out of the GPS unit and translates it into the designated datum. ArcView's default set-up is "Geographic," which is Decimal Degrees and NAD 83, so that is a good starting point.)

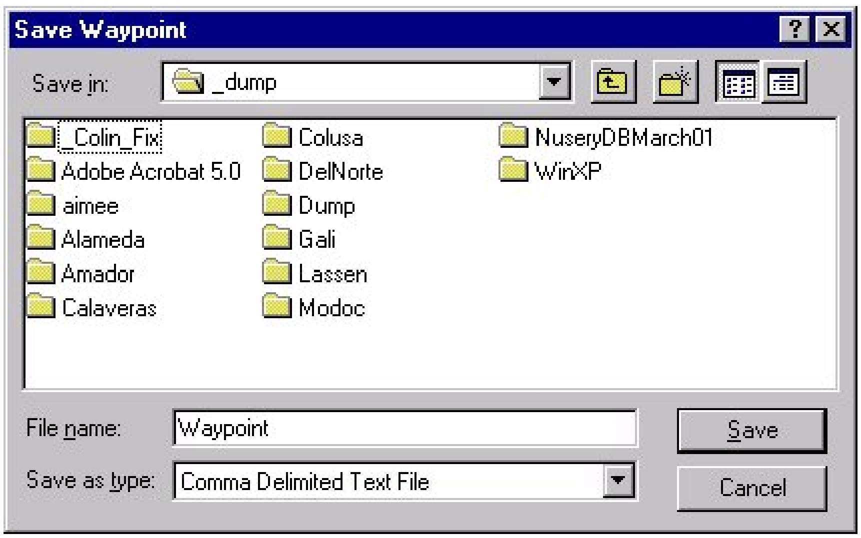




Step 3. Go to GPS-Port and make sure it is set to the port you are using (generally COM1).

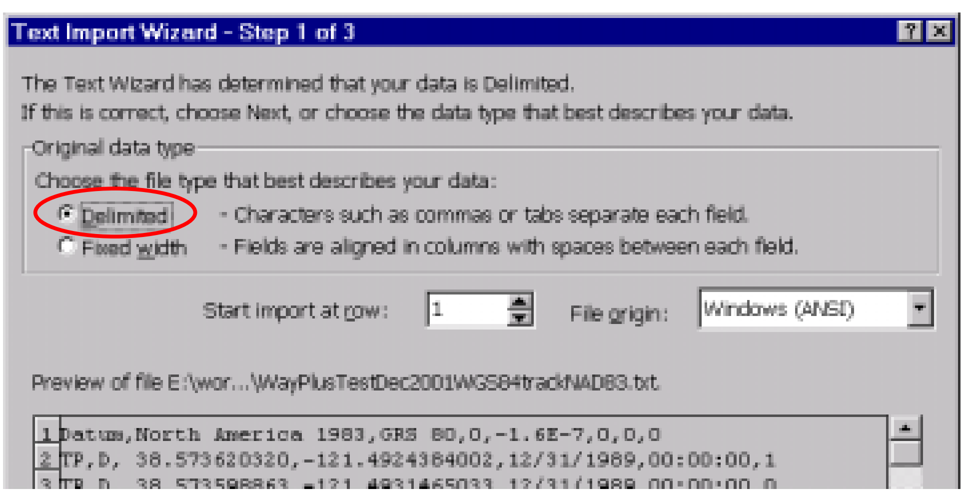


Step 4. Select Waypoints-Download or GPS-Download from GPS-Waypoints to download your waypoints (or tracks or routes). Save the waypoints as "comma delimited textfile" (File-Save-Waypoint). Make sure to note where you saved it.

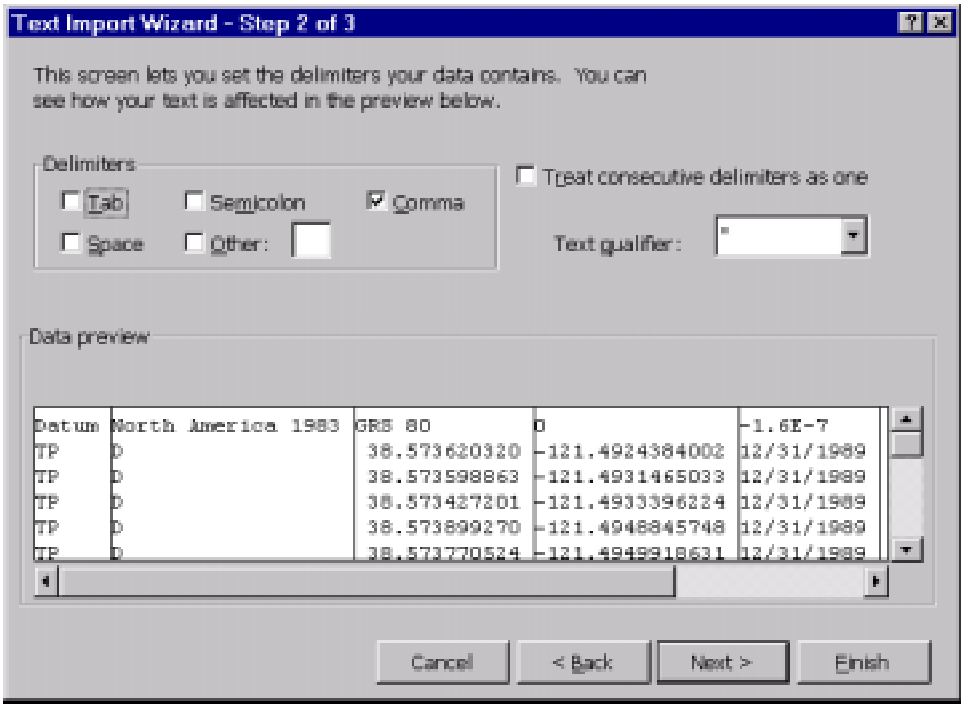


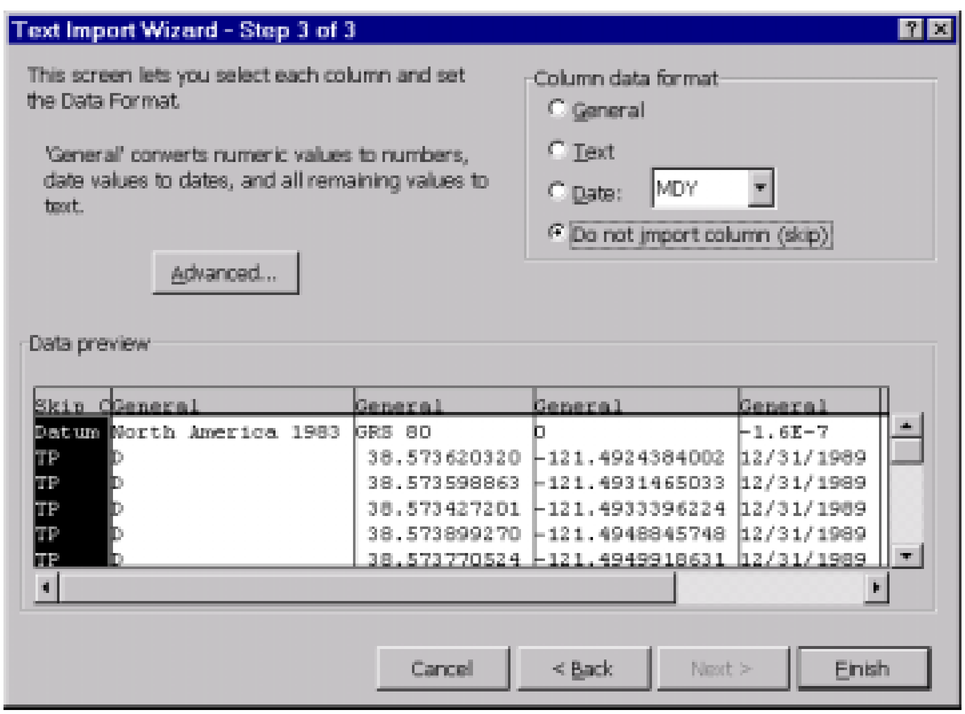
Step 5. At this point you can use AV Garmin from the California Dept. of Fish and Game or Garmin.avx. Or you can:

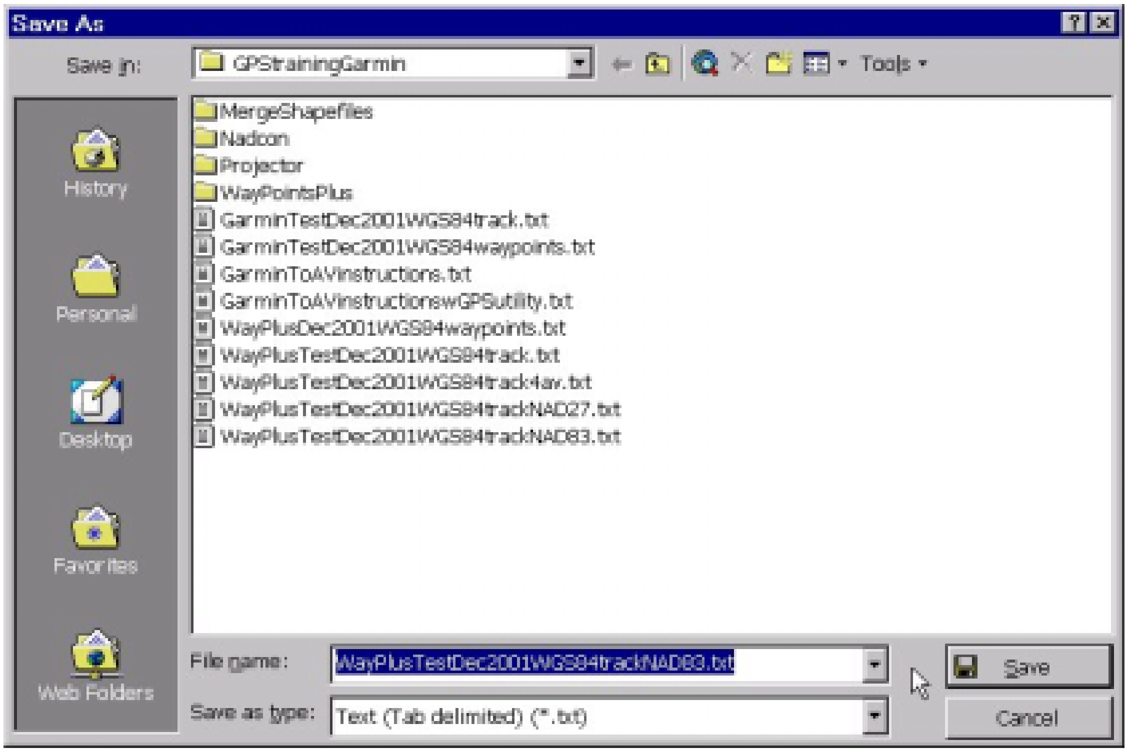
Step 6. Open into Excel. As you are bringing in the file, be sure to select delimited instead of fixed



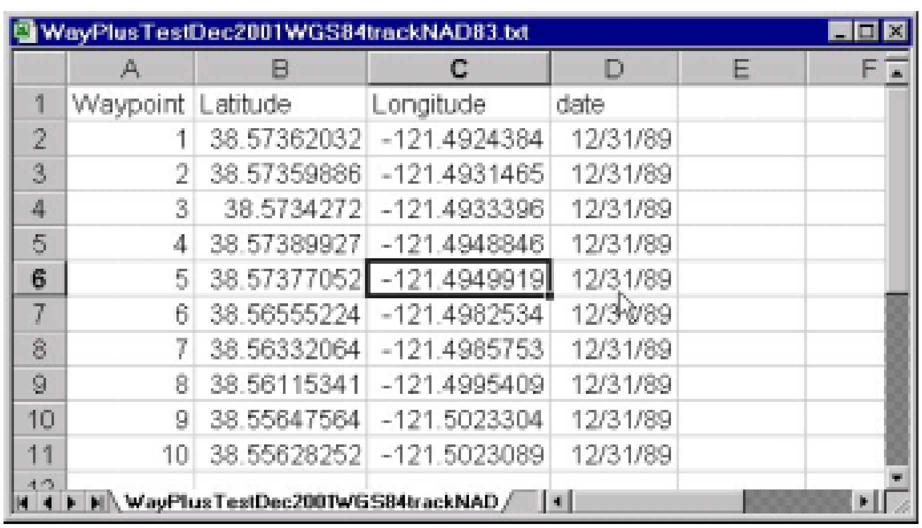
width, and use a comma as the delimiter. Don't import any columns you don't need. Once it is in Excel, get rid of any extra rows. Bringing it into Excel mostly allows you to make sure that it is in a format that ArcView will read. Save the table in .txt format again (tab delimited is fine). Overwriting your file is generally fine.







What your file should look like:

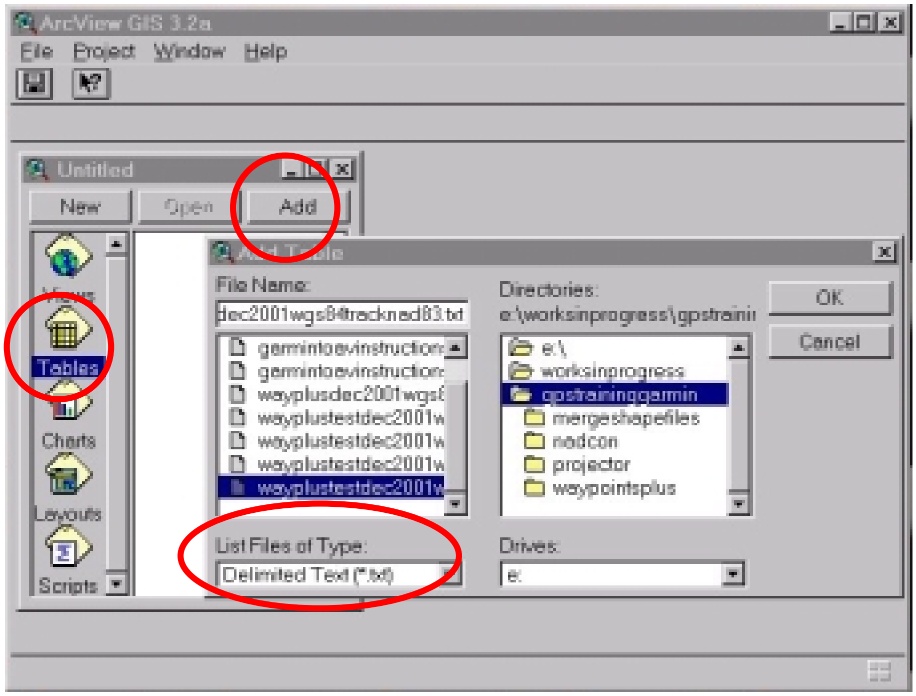

WayPlusTestDec2001WGS84trackNAD83.txt

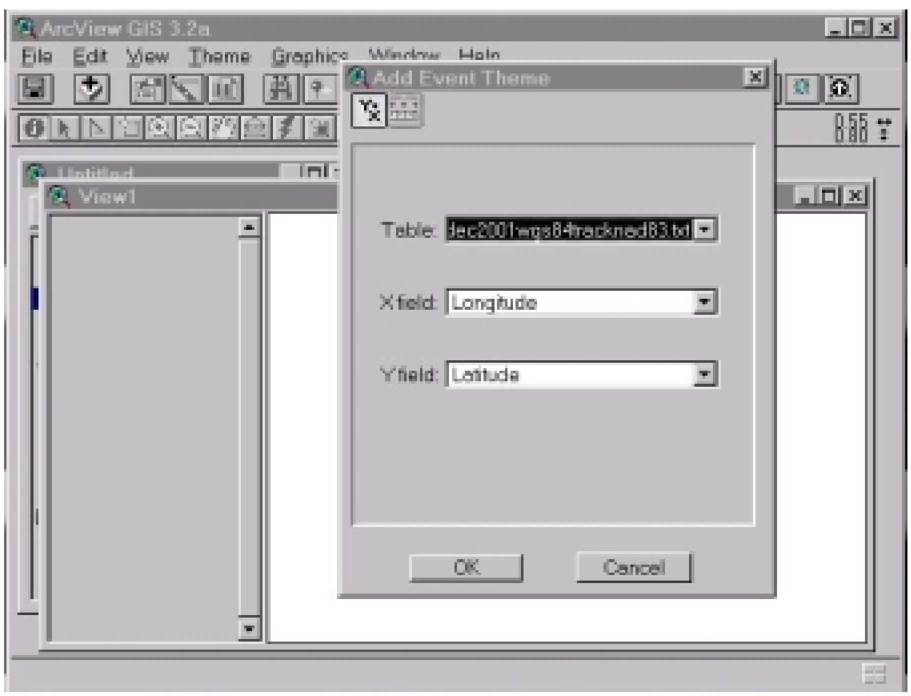
	A	B	C	D	E	F
1	Waypoint	Latitude	Longitude	date		
2	1	38.57362032	-121.4924384	12/31/89		
3	2	38.57359886	-121.4931465	12/31/89		
4	3	38.5734272	-121.4933396	12/31/89		
5	4	38.57389927	-121.4948846	12/31/89		
6	5	38.57377052	-121.4949919	12/31/89		
7	6	38.56555224	-121.4982534	12/31/89		
8	7	38.56332064	-121.4985753	12/31/89		
9	8	38.56115341	-121.4995409	12/31/89		
10	9	38.55647564	-121.5023304	12/31/89		
11	10	38.55628252	-121.5023089	12/31/89		

WayPlusTestDec2001WGS84trackNAD

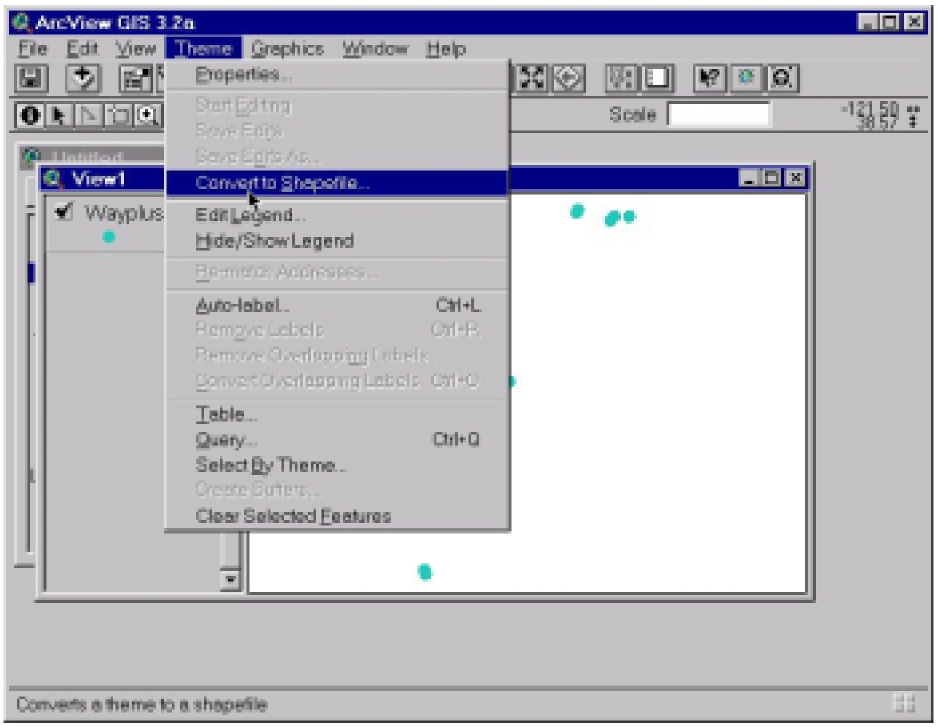
If you don't have a Garmin GPS and have succeeded in getting your GPS unit to download your waypoints into a text file, you may find that your coordinates use N and W instead of + and -, and that there is a bunch of header information that keeps the data from looking like a neat arrangement of rows and columns Delete the header information. Using Search-Replace to replace the N and W directional information with just the numbers. For example if the latitude longitude for Sacramento was N38 W121 then do one replace (Find N3, Replace with 3) for the latitude coordinate; one for the longitude coordinate (Find W1 , Replace with -1). If you have both the tracks and waypoints in one file; cut out the track points and put them into a separate text file. Save all files. Tab delimited text is fine.

Step 7. Open Arcview. Make the tables active and add your .txt file. Then open a view and under the view menu select Add Event Theme. Select your .txt table, and make the longitude field your x field and the latitude field your y field. Hit OK. You should now see points in your view.





Step 8. Convert this to a shapefile. With the view open, make your text theme active by clicking on its legend (it will look like a raised button). Go to Theme-Convert To Shapefile, and save it into your chosen data folder. At this point you will need to do whatever projection and datum conversions you need to get the shapefile into your system. (See th e Dept. of Parks and Resources' webpage for a comparison of ArcView's projection utility to Projector! and NADCON extensions.) If you use AV Garmin, most of these steps can be eliminated.



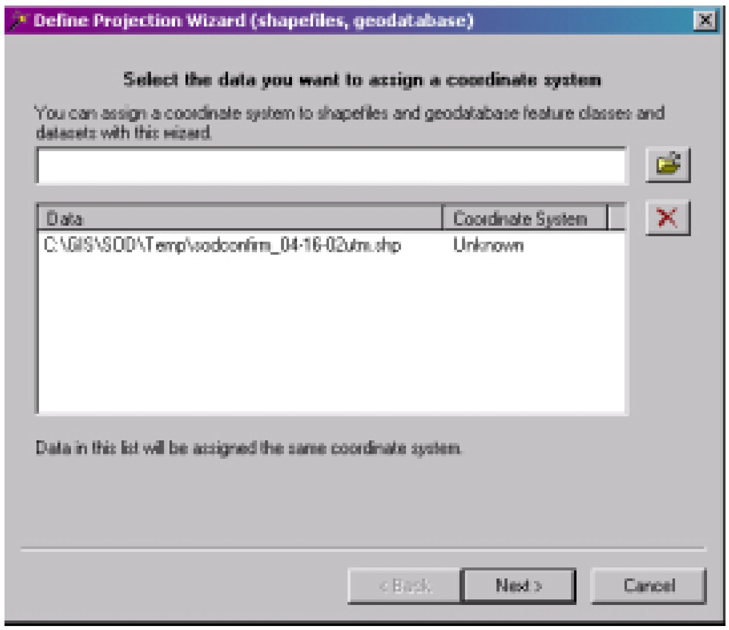
4.6 Reprojecting Using ArcToolbox

This section describes the process of reprojecting from UTM NAD 83 Zone 10 to the custom Teale-Albers projection that's used by state agencies.

Step 1. Open ArcToolbox.

Step 2. Double-click on 'Define Projection Wizard (shapefiles, geodatabase).'

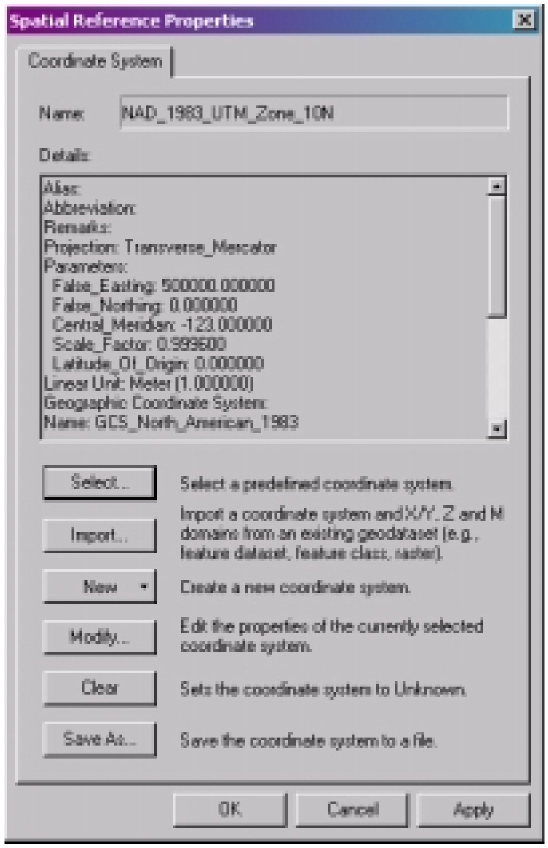
Step 3. Browse to your theme in the temp directory, and click 'Next'. (See figure at right.)



Step 4. Click on 'Select Coordinate System…'. Click on 'Select…' to select a predefined coordinate system.

Step 5. Choose Projected Coordinate System, then UTM, then NAD 1983, then NAD 1983 UTM Zone 10N.prj

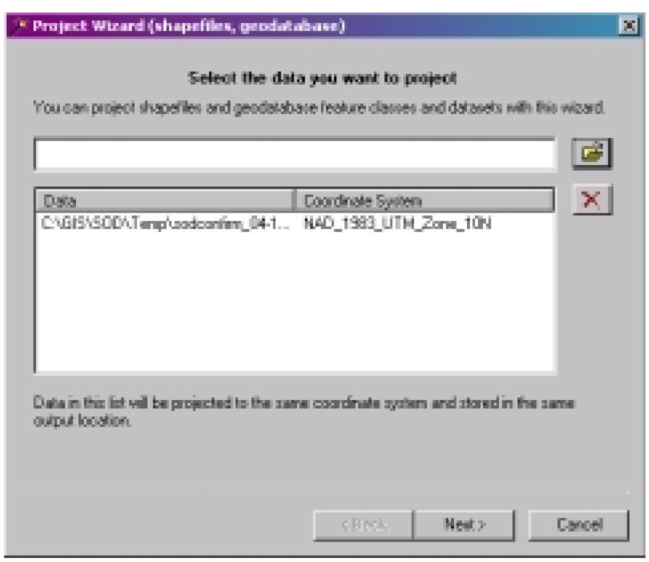
Step 6. Click on 'Add' to assign the coordinate system.



Step 7. Click ‘OK’, then ‘Next’, then ‘Finish.’

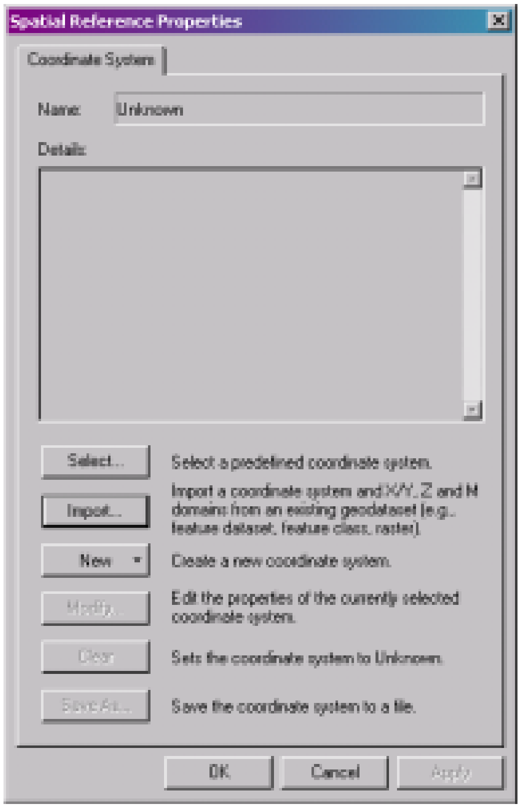
Step 8. Double-click on the ‘Project Wizard (shapefiles, geodatabase)’.

Step 9. Browse to your theme in the temp directory. Notice how this time there is a projection assigned to it (what you did earlier in the step). Click ‘Next’.

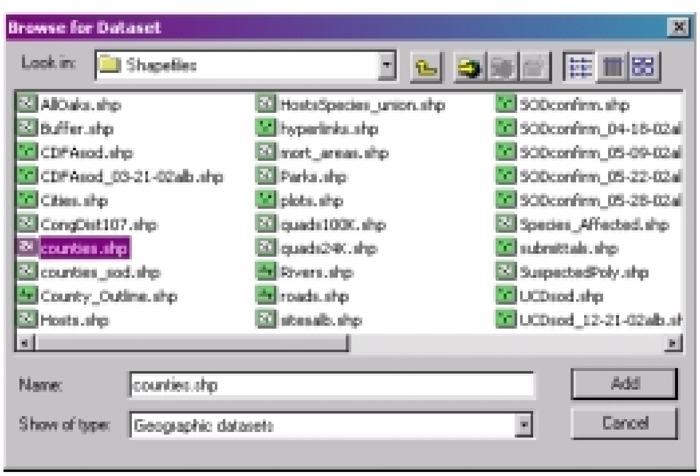


Step 10. Browse to C:\GIS\SOD\Shapefiles\, which is where you want to save the new shapefile. Assign a name to your newly-projected theme (e.g. SODconfirm_04-16-02alb.shp) and click 'Next'. Notice the 'alb' in the shapefile name; it stands for 'albers' projection.

Step 11. Click on 'Select Coordinate System…' and then click on 'Import…'

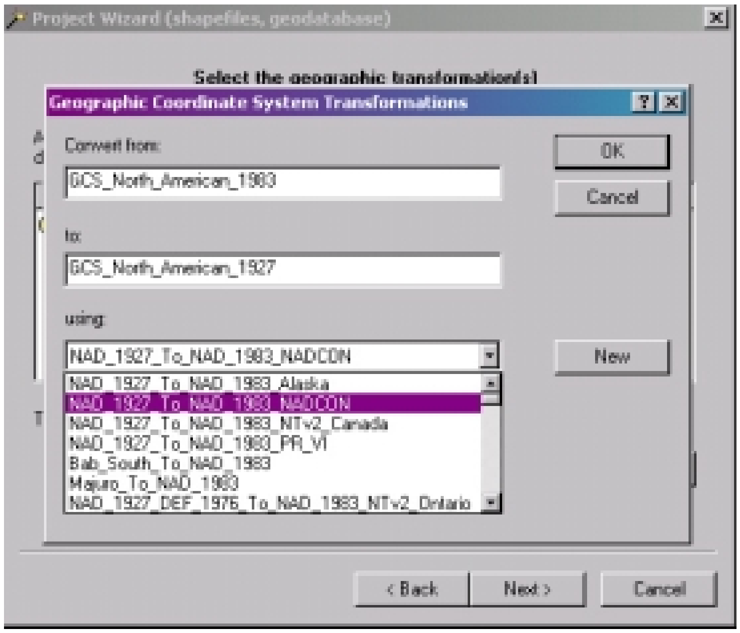


Step 12. Browse to C:\GIS\SOD\Shapefiles\, and choose counties.shp. This will import the same projection file of counties.shp into your new SODconfirm_xx-xx-02 shapefile. Click 'Add', then click 'OK', then click 'Next'.

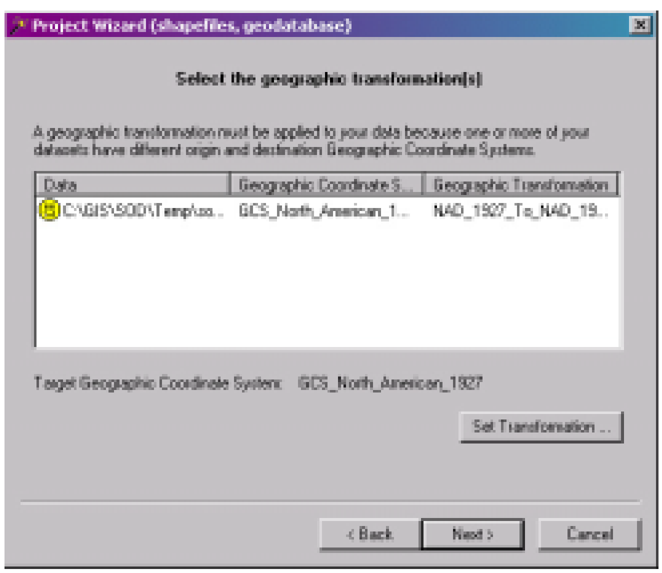


Step 13. The next step asks you to set the geographic transformation (this is needed when you re-project from one datum to another). Since we are re-projecting from UTM NAD 1983 to Custom Albers with NAD 1927 datum, we need to set a geographic transformation. Click on 'Set Transformation…'

Step 14. From the drop-down box, choose 'NAD_1927_To_NAD_1983_NADCON' and click 'OK'.



Step 15. The sad face should be happy now.



Step 16. Click 'Next'. Then click 'Next' again. (Don't change the coordinate extents for the output dataset.)

Step 17. Double-check your parameters and transformation in the summary. It should read:

```
Input Datasets:
  C:\GIS\SOD\Temp\sodconfirm_05-09-
02utm.shp


New location:
  C:\GIS\SOD\Shapefiles\SODconfirm_05-09-
02alb.shp

Projected Coordinate System
  Alias:
  Abbreviation:
  Remarks:
Projection: Albers
Parameters:
  False_Easting: 0.000000
  False_Northing: -4000000.000000
  Central_Meridian: -120.000000
  Standard_Parallel_1: 34.000000
  Standard_Parallel_2: 40.500000
  Latitude_Of_Origin: 0.000000
Linear Unit: Meter (1.000000)
Geographic Coordinate System:
  Name: GCS_North_American_1927
  Alias:
  Abbreviation:
  Remarks:
  Angular Unit: Degree
(0.017453292519943295)
  Prime Meridian: Greenwich
(0.000000000000000000)
  Datum: D_North_American_1927
    Spheroid: Clarke_1866
      Semimajor Axis:
6378206.400000000400000000
      Semiminor Axis:
6356583.799998980900000000
      Inverse Flattening:
294.978698200000000000
```

Step 18. If everything looks good, click 'Finish'.

Step 19. Close ArcToolbox.

4.7 Resources on the Web

The following are useful websites recommended by GIS professionals Rosie Yacoub (CDFA) and Maggi Kelly (UCCE).

http://www.cdpr.ca.gov/docs/county/pumpdvlp/arcvwitm/extentls.htm
Basic extensions you will likely use in ArcView 3.2.

http://www.fs.fed.us/database/gps/
Forest Service page for locating Community Base Station for post-processing differential corrections.

http://www.joe.mehaffey.com/
Great resource for learning about different GPS devices, especially recreation-grade devices.

http://www.tapr.org/~kh2z/Waypoint/
Get Waypoints Plus here, the software extension that downloads waypoints from Garmin GPS units into a format usable by AV Garmin and TOPO!

http://www.directionsmag.com/
Online GIS magazine with discussion groups, utility downloads (extensions), and online utilities like decimal degree – degree –minute – second converter.

http://www.calflora.org/
Calflora’s webpage. Includes distribution information for weeds and other plants in CA.

www.nawma.org/documents/Mapping%20Standards/Mapping%20Standards%20Index.html
North American Weed Management Association’s weed mapping standards.

http://www.cdfa.ca.gov/phpps/ipc/noxweedinfo/noxwdinfo_hp.htm
CDFA’s “encycloweedia.”

http://romberg.sfsu.edu/~egeria/Weed_Conference/conference_presentation.htm
Really neat presentation of how a remote sensing technique was developed for mapping *Egeria* in the San Joaquin-Sacramento Delta.

http://gis.esri.com/arcscripts/index.cfm
Since you need scripts to do a lot of basic stuff in ArcView, make this link your friend. AVGarmin available here.

http://www.colorado.edu/geography/gcraft/contents.html
The Geographer's Craft - source for remote sensing / GIS /GPS information, lecture notes, and information.

http://personal.cmich.edu/~franc1m/homepage.htm
University of Michigan Resources for Earth Science and Geography Education. This site has tons of spatial related links.

http://www.sonoma.edu/GIC/Geog387/GIS-Links.html
Sonoma State's GIS page. Has overviews and lots of other links to all things GIS.

http://www.gisportal.com/
The GIS portal has links for GIS and Industry.

http://www.greeninfo.org/
GreenInfo Network's mission is to bring the power of computer-based mapping to non-profits, public agencies and other public interest organizations.

http://www.spatialnews.com/
Spatial News - on-line GIS magazine: SpatialNews provides the latest news, educational resources, data pointers, and commentaries to thousands of GIS, CAD, GPS, map (and digital mapping), and location-based services (LBS) industry professionals and students every day.

The following list was generated for the "WMA Resource Book, 2000" by Chris Crown of CSU Chico and Butte. The list is meant to get you started - there are literally thousands of sites out there. Most of these include great links to other great sites with links to more great sites and so it goes.

GIS AND RELATED EMPLOYMENT

The GIS jobs clearinghouse	Great site! GIS job leads/links to more GIS job sites.	http://www.gjc.org
GeoWeb (GIS/GPS/RS)	Post a resume/fee for job listings	http://www.ggrweb.com/job.html
GeoSearch	Jobs with GeoSearch Inc./others /relocation tools	http://www.geosearch.com
GISjobs.com	One of the best rated sites for GIS jobs	http://www.gisjobs.com/
GeoJob Source.	Career opportunities in spatial data professions	http://www.geojobsource.com/careerop.htm
U of Washington Geography Jobs	Links for Geog/GIS & related jobs, job search tips	http://depts.washington.edu/geogjobs/
Environmental Jobs and Careers	Environmental jobs & careers links/search info	http://www.ejobs.org/

GIS SOFTWARE VENDORS

ESRI	Leading GIS software develp/lots of info/links/educ.	http://www.esri.com
ESRI, CANADA	ESRI's Canada site – Canadian links/educ. materials	http://www.esri.ca
Bentley Systems	Geoengineering software products/Microstation	http://www.bentley.com
Autodesk	Check out Autodesk World	http://www.autodesk.com/solution/gis/index.htm
Intergraph	Check out software, then category GIS	http://www.intergraph.com
Caliper	Maptitude Desktop GIS software	http://www.caliper.com
MapInfo	Find out more about this desktop GIS	http://www.mapinfo.com
IDRISI	A raster-based GIS f/ School of Geography,Clark U.	http://www.clarklabs.org
Microsoft MapPoint for Office	Integrates with office –very basic mapping &analysis	http://www.microsoft.com/office/mappoint

FEDERAL GOVERNMENT

USGS (click on the mapping link)	good info on TIGER, DLG, DOQQ & DEM	http://www.usgs.gov
FGDC	Site for geospatial data, metadata info and tutorials	http://fgdc.er.usgs.gov
Census Bureau	U.S. Census Data *Check ESRI f/free census dwnld.	http://www.census.gov
U.S. Fish and Wildlife Service	Wetlands information/data	http://www.nwi.fws.gov
Bureau of Land Management	GEOSPATIAL Home Page	http://www.blm.gov/gis
Sandia National Laboratory	GIS applications, tips, tutorials	http://www.sandia.gov/GIS/gis.html
GIS at BC Env., Lands, and Parks	A wonderful list of links, incl. Tutorials, data	http://www.env.gov.bc.ca/gis

STATE GOVERNMENT/LOCAL GOVERNMENT (Mostly California - more under data & applications)

California Spatial Information Library (CaSIL)	California Spatial Data Sets for download, created by CERES (takes the place of Teale Data Center)	http://www.gis.ca.gov
Info Center for the Environment (ICE)	U.C. Davis - watershed and env. related information	http://ice.ucdavis.edu
CERES	California Environmental Info. Catalog/metadata	http://ceres.ca.gov
California Dept of Forestry	CDF's Fire & Resource Assess. Prog. – data , maps	http://frap.cdf.ca.gov
California Dept. Of Water Res.	Division of flood management data exchange center	http://cdec.water.ca.gov
Oregon State Service Center for GIS	Info and links to Oregon GIS activities & data	http://www.sscgis.state.or.us
Texas Natural Resources Info Cent.	Data, resources	http://www.tnris.state.tx.us
Arizona Geographic Info.Council	Pub. Info. site – good Arizona & metadata links	http://www.state.az.us/gis3/agic/agichome.html

COLLEGES/UNIVERSITIES

Center for Adv. Spatial Technology-	Links to GIS data and Projects	http://www.cast.uark.edu/local/gis
Ohio State U. Center for Mapping	Great site for users of mapping technologies	http://www.cfm.ohio-state.edu
CALMIT - Nebraska	Center for Advanced Land Mngmnt – Midwest Links	http://ulysses.unl.edu/calmit/research.html
University of Texas, Austin	Geographers' Craft - GREAT site for geog/GIS	http://www.utexas.edu/depts/grg/gcraft
U. Of Edinburgh, U.K	General GIS information and linkes/GIS dictionary	http://www.geo.ed.ac.uk/home/gishome.html
Cal Poly, San Luis Obispo	School of Landscape Architechure GIS Tech Lab	http://suntzu.larc.calpoly.edu/gislab
California State University, Chico	CSU, Chico Geographical Information Center	http://www.gic.csuchico.edu
Pennsylvana State University	Online 4-course GIS Certificate Program	http://www.gis.psu.edu

Virtual Geography Department	GIS/RS and Cartography courses on-line	http://www.utexas.edu/depts/grg/virtdept/contents.html
University of Arizona	Creating a campus wide GIS	http://w3.arizona.edu/~cfp/maps_data/campus_gis.shtml

TRAINING/EDUCATION MATERIALS

University of Texas, Austin	Highly respected and much used site for GIS/GPS ed	http://www.utexas.edu/depts/grg/gcraft/contents.html
CCITT Project	Curric. Materials: GIS, Remote Sensing, Image Pr.	http://earth.fhda.edu/index.html
NCGIA (GIS Core Curric. Link)	National Center for Geographic Info & Analysis	http://www.ncgia.ucsb.edu
Core Curric. for Tech. Programs	GIS Curriculum materials for Instructors	http://www.ncgia.ucsb.edu/cctp
U. Maine (has been off-line lately)	GIS Literature Database - search for articles/papers	http://www.odyssey.maine.edu/gisweb
UCGIS	Univ. Consortium Geographic Information Science	http://www.ucgis.org
ESRI Education Pgs	Clic Higher Education or K-12 link	http://www.esri.com/industries/index.html

GIS PUBLICATIONS ONLINE/DISCUSSION GROUPS

Spatial News	Daily News for GIS, CAD & Mapping Community	http://www.spatialnews.com
Geoplace.com	A lot here - site for GIS World Magazine, GeoNews	http://www.geoplace.com
Sacramento Area ArcView UserGrp	Every other month meetings w/presentations Free	http://www.dcn.davis.ca.us/~arcview/
ESRI WEB site user group info.	ESRI user group info	http://www.esri.com/usersupport/usergroups/usergroups.html
URISA – nice resource f/GIS users	Urban and Regional Information Systems Assoc.	http://www.urisa.org
BAAMA	Bay Area Automated Mapping Assoc.	http://www.baama.org
Directions Magazine online	A must see, check out tools link	http://www.directionsmag.com
Geography & GIS Mailing Lists	List of various groups you can subscribe to	http://www.gisnet.com/notebook/index.html

ESPECIALLY GOOD LINK LISTS

MapInfo User Links	Not just for MapInfo users...check it out.	http://www.research.umbc.edu/~roswell/mipage.html
GIS Portal: Great GIS NetSites	If you could only go to one site for GIS links…	http://www.gisportal.com
GISLinx	Many categories of GIS LINKS (jobs, data, orgs…)	http://www.gislinx.com

2.5 GIS TUTORIALS/UTILITIES

USGS GIS Tutorial	What is GIS? Tutorial	http://www.usgs.gov/research/gis/title.html
Sandia National Laboratories	IAC - tutorial especially for the systems analyst	http://www.sandia.gov/GIS/tutrs/iactut2.html
Sweden GIS	What a great site! - Demos/Avenue scripts/links	http://www.swegis.com
ARC/INFO Tutorial	Do a lesson or download the ARC/INFO coverages	http://boris.qub.ac.uk/shane/arc/ARChome.html
University of	GIS Dictionary	http://www.geo.ed.ac.uk/agidict/welcome.html

Edinburgh		
British Columbia Ministry of Env.	Map projections (check out Geographers' Craft too)	http://srmwww.gov.bc.ca/gis/projectiontutorial.html
Electronic Textbook: Statsoft	Training in understanding & application of statistics	http://www.statsoft.com/textbook/stathome.html
Sandia National Laboratories.	ArcView/Avenue: Coding Styles and Utility Scripts	http://www.sandia.gov/GIS/tech/avcsus.htm
GIS Guide to Good Practice	emphasis upon archaeological data but widely applic	http://ads.ahds.ac.uk/project/goodguides/gis
ESRI Virtual Campus	Software & Applications courses , reasonably priced	http://campus.esri.com/campus/home/home.cfm

APPLICATIONS (more in other sections too)

EPA	Click on Projects & Programs/databases & software	http://www.epa.gov
FEMA	Federal Emergency Management Agency	http://www.fema.gov/maps
USGS	Natural Disast. Reduct./Plan for Nation Res. Priorit.	http://www.usgs.gov/sndr/index.html
USGS	Water related sites and data	http://water.usgs.gov/public/GIS
NOAA	National Geophysical Data Center	http://www.ngdc.noaa.gov
California Environmental Information Catalog	Metadata creation application by CERES, ties your metadata into the NSDI Clearinghouse and CaSIL	http://ceres.ca.gov/catalog/metadata.html
Sandia National Laboratories.	Projects incl. Transportation Data Analysis &Visual.	http://www.sandia.gov/ttp/projects/gis.html
Ames Research Laboratory	NASA Ames Research - GIS and Disease	http://geo.arc.nasa.gov/esdstaff/health/bydisease.html
Camp Pendleton	Harvard School of Design	http://www.gsd.harvard.edu/brc/brc.html
California Dept. Of Water Res.	Division of flood management data exchange center	http://www.ceres.ca.gov/flood
Boulder County Colorado land use	GIS, Wildfires and Landuse Planning, Internet GIS	http://pasture.ecn.purdue.edu/~aggrass/esri95/to250/p2101.html
Access USGS San Francisco Bay	Info and digital DATA for the bay esp. water	http://sfbay.wr.usgs.gov
Gov's Office of Emergency Services	see California Emergency Plan - PDF	http://www.oes.ca.gov
REGIS GRASSLinks	Public Access GIS for Bay Area	http://regis.berkeley.edu/grasslinks/index.html
San Luis Obispo Geographic Info	Consortium (SLOGIC) data/projects	http://www.slogic.org
City of Ontario, California	Online applications/info on how they started	http://gis.ci.ontario.ca.us/gis/index.htm
Island Resources Foundation:	Cruise to the section on GIS and Carribean islands	http://www.irf.org/ir_isis.html
Archaelogy links	Several good links for GIS in Archaelogy here	http://users.erols.com/gourad
NIJ and Hunter College	Crime Mapping and Analysis/Links to other proj.	http://everest.hunter.cuny.edu/capse/projects/nij/crime.html
Professor Maidment's site	GIS & Hydrology, courses, links, projects	http://www.ce.utexas.edu/prof/maidment
Earthsat Company	Great flood of 1993& GIS, Ag., geology...	http://www.earthsat.com/index.html
World Health Organization	Division of Tropical Diseases/GIS	http://www.who.int/ctd/index.html

RiskINFO	Insurance - Emergency Risk Management	http://www.riskinfo.com/tech/feature5.html
ESRI	Many apps here - see 'Your Industry' link	http://www.esri.com/industries/index.html
ESRI Conference Archives	Papers & Abstacts for many fields & applications	http://www.esri.com/library/userconf/archive.html

DATA (see State & Local Gov't, University, Application sites for more)

California Spatial Information Library (CaSIL)	California Spatial Data Sets for download (free), created by CERES (replaced Teale Data Center)	http://www.gis.ca.gov
U. N. Databases.	In table format, social indicator statistics	http://www.un.org/databases
U.S. Department of Transportation	Office of Geographic Information Services	http://www.bts.gov/gis
Centers for Disease Control & Prev.	USA Dept. Of Health & Human Serv.– Data & Stats	http://www.cdc.gov

National Spatial Data Clearinghouse	Standards, metadata, data	http://www.fgdc.gov/fgdc/fgdc.html
USGS	Lots of data	http://www-nmd.usgs.gov
USGS Coastline extractor	Extract the section of coastline you want	http://crusty.er.usgs.gov/coast/getcoast.html
NOAA	Environmental data – GLOBE program info/data	http://www.noaa.gov
Global Change	Links, some to Global Environmental data sources	http://www.globalchange.org/infoall/links-u.htm
Sandia National Laboratories	Data Checklist, before purchase	http://www.sandia.gov/GIS/tutrs/datachk.html
Metadata web site	Info & links - see BLM "Barney" metadata tutorial	http://www.blm.gov/gis/nsdi.html
USGS Nat'l Spatial Data Clearingh.	Info and Links to spatial data standards/metadata	http://nsdi.usgs.gov
U.S. State & local GIS links	Links – many for statewide data	http://www.library.cornell.edu/okuref/maps/state.htm
CA dept. of Forestry & Fire Protect.	FRAP - Metadata and data to download	http://frap.cdf.ca.gov/data/frapgisdata/select.asp
San Francisco Bay Area DEM's	Also links to other data and a few other areas	http://www.lib.berkeley.edu/EART/digital/dem
California Geographical Survey	Census data & DEM's for California and other data	http://geogdata.csun.edu
Verde Watershed. GIS file - Arizona	library of (GIS) data and maps	http://www.verde.org/covers.html
Iowa Dept. of Natural Resources	Nice interface f/regional & state Nat. Resources data	http://www.igsb.uiowa.edu/nrgis/gishome.htm
The Alexandria Project	Links - search by subject for GIS and RS data	http://www.alexandria.ucsb.edu
Center Adv. Spatial Technologies	(CAST) National DB of GIS data/JapanGIS Guide	http://www.cast.uark.edu/local/links/gis/local.html
Center for Advanced Spatial Tech.	(CAST) Guide to mostly free & mostly online data	http://www.cast.uark.edu/local/hunt/index.html
ESRI	Free downloadable data, including CENSUS data	http://www.esri.com/data/index.html
ESRI's ArcData	Variety of commercial data to use	http://gis.esri.com/metadata/directory.cfm

Partners Catalog	w/ESRI software	
Microsoft's terraserver.com site	Free and for Fee imagery and ways to use it	http://www.terraserver.com
Claritas	Sells spatial data for marketing, health care	http://www.claritas.com
Geographic Data Technology -GDT	A respected developer of up-to-date data (not free)	http://www.geographic.com

GPS & GIS RELATED TECHNOLOGIES

University of Texas, Austin	GPS information	http://www.colorado.Edu/geography/gcraft/notes/gps/gps_f.html
Trimble Corporation	Nice GPS Tutorial	http://www.trimble.com
Forest Service	GPS base stations clickable map (incl. Trimble)	http://www.fs.fed.us/database/gps/clickmap/cbsmap.htm
Informational hub for GPS units.	Covers different kinds of GPS units, software, white papers.	http://www.joe.mehaffey.com
Etak affordable online geocoding	From set of addresses quickly returns lat/long	http://www.etak.com

MENTIONABLES

Amazon.com bookstore	Great prices on GIS books - order on line	http://www.amazon.com
Making maps easy to read	U. College London	http://www.nottingham.ac.uk/education/maps
Calculator's online	You name it, its here	http://www-sci.lib.uci.edu/HSG/RefCalculators.html
ZD Net – terrific resource	Reviews: computers,components/on-line comp. mags	http://www.zdnet.com
MapQuest Travel	Online address locator	http://www.mapquest.com

WEED SPECIFIC

BLM Noxious Weed page	Links to documents & state weed pages	http://www-a.blm.gov/weeds
NAWMA home page	N. American Weed Management Association—links to their mapping standards	http://www.nawma.org/
CDFA's 'Encycloweedia'.	photos & descriptions of all CDFA rated weeds	http://www.cdfa.ca.gov/weedinfo
California Noxious Weed Control Project Inventory	Lists projects by weed, county, control method	http://endeavor.des.ucdavis.edu/weeds
CDFA Noxious Weed Information Project	Links to Purple Loosestrife, Noxious Times, Yellow Starthistle Mapping Project, more…	http://www.cdfa.ca.gov/weedhome
California Noxious Weed Control Project Inventory	Lists projects by weed, county, control method	http://endeavor.des.ucdavis.edu/weeds
California Exotic Pest Plant Council	Includes pest plant lists and other web links	http://www.caleppc.org/
California Native Plant Society	Invasive Exotic plant web links. Includes URLs for general information, biocontrol, integrated pest management, and selected target species	http://www.cnps.org/links/exotics_links.htm

Nature Conservancy's Wildlands Invasive Species Program	Photos for identifying weeds, weed alerts, stewardship control and management information	http://tncweeds.ucdavis.edu/
University of California Weed Research and Information Center	Weed information and education	http://wric.ucdavis.edu/aboutwric/staff.htm
Plant Conservation Alliance's Alien Plant Working Group	Information and fact sheets	http://www.nps.gov/plants/alien/index.htm
Southwest Exotic Mapping Program (SWEMP)	Includes interactive weed maps	http://www.usgs.nau.edu/swemp
Team Arundo del Norte (TAdN)	Arundo mapping protocol with instructions and online database	http://teamarundo.org
CRISIS Maps (by the California Information Node of the NBII)	Interactive maps with data combined from SWEMP, CalFlora, and TAdN based on a common standard	http://cain.nbii.gov/crisis/crisismaps

OTHERS

Basic extensions you WILL use in ArcView 3.2	http://www.cdpr.ca.gov/docs/county/pumpdvlp/arcvwitm/extentls.htm
Hooray for some good instructions for how to deal with projections in AV 3.2!	http://www.cdpr.ca.gov/docs/county/pumpdvlp/devgrp/prjctdta/pres0401.htm
Forest Service page for locating Community Base Station for post-processing differential corrections	http://www.fs.fed.us/database/gps/
great resource for learning about different gps devices, especially recreational grade devices	http://www.joe.mehaffey.com/
Get Waypoints plus here (downloads Waypoints from Garmin GPS into a format usable by AVGarmin	http://www.tapr.org/~kh2z/Waypoint/
online GIS magazine with discussion groups, utility downloads (extensions), and online utilities like decimal degree – degree –minute – second converter	http://www.directionsmag.com/
Calflora's webpage. Includes distribution information for weeds and other plants in CA	http://www.calflora.org/
North American Weed Management Association's weed mapping standards.	http://www.nawma.org/documents/Mapping%20Standards/Mapping%20Standards%20Index.html
CDFA's encycloweedia	http://www.cdfa.ca.gov/phpps/ipc/noxweedinfo/noxwdinfo_hp.htm
really neat presentation of how a remote sensing technique was developed for mapping Egaria in the San Joaquin-Sacramento Delta	http://romberg.sfsu.edu/~egeria/Weed_Conference/conference_presentation.htm
Since you need scripts to do a lot of basic stuff in ArcView, make this link your friend. AVGarmin available here.	http://gis.esri.com/arcscripts/index.cfm

4.8 Case Study: Drawing the Line on Yellow Starthistle Spread in the Mid-Elevational Sierra Nevada

The California Department of Food and Agriculture (CDFA) mapped and assessed the yellow starthistle (YST) population in the foothills of the Sierra Nevada in cooperation with a variety of other governmental and private groups, mostly by participation of these groups in Weed Management Areas. The mapped infestations were turned over to the Weed Management Areas, to be used in preventing the spread of YST into the mid- and high-elevation Sierra by focusing eradication efforts on the eastern extent of YST.

Background

Yellow starthistle (YST) is a noxious, invasive, non-native weed spreading rapidly in California. Between 1869 and 1997, populations in California expanded from zero to 12 million acres. While YST is beyond eradication, valuable lands may still be protected from its effects. Complete statewide eradication would cost billions of dollars and engage tens of thousands of people for many years, making it economically and politically unfeasible, even if it were technically possible. Lands free of YST still exist, but it is apparently still on the move, threatening these remaining resources. One such zone is the western Sierra foothills and middle elevations (5-9000 feet), where YST appears to be moving up slope from the Great Valley. If control efforts were focused on the prevention of further spread and on local eradication in such an area, large tracts of important public and private land might be preserved from degradation. In addition, the infested acreage along the advancing edge might be relatively small, such that the cost of control would be correspondingly small, especially compared to the value of the area to be protected. However, better mapping of the YST infestation along the leading edge is necessary to determine how far it has moved up slope and to provide estimates of the area needing treatment and of the attendant costs. Such mapping would also provide agencies and private landowners better information for prioritizing control and eradication efforts.

In this context, the purpose of this project was to provide the basis for prioritized control of yellow starthistle by providing a landscape-level view of the extent of YST.

Objective 1

Initiate a cooperative project that involved resource management professionals and qualified amateurs in mapping yellow starthistle throughout the Sierra Nevada. CDFA coordinated YST mapping mainly through participation in Weed Management Areas (WMAs). Base maps and mapping instructions were developed for the project. The instructions and results from a previous survey were posted on an Internet site explaining the project. A project coordinator attended 8 meetings with the Weed Management Areas in the spring to explain the goals of the project, and distribute maps and mapping instructions. During the course of these meetings, contact was made with individuals who committed to sharing their findings of YST with the project. The contact information for these people was entered into a database, and they were called to check on the status of mapping efforts, and collect data. The following organizations participated in the project by mapping locations of YST and sharing them with CDFA:

County Agricultural Departments
US Forest Service
California Native Plant Society
National Park Service
US Geological Survey
Natural Resource Conservation Service
Sierra Pacific Industries
UC Cooperative Extension

Objective 2

Complete an intensive survey of Sierra Nevada roads for the presence of yellow starthistle. Two CDFA seasonal staff were trained in identifying YST along roadsides and use of GPS units. Both Trimble Pro XL GPS Garmin III GPS units were used. The survey included some of the highways that had been surveyed in 1999 by CDFA and CalTrans, plus a number of smaller roads generally transecting the Sierra Nevada from west to east (see attachment B for survey schedule). The roads surveyed were sometimes chosen at the suggestion of project cooperators from the Weed Management Areas. During the course of the summer, the Scientific Aides completed the survey, downloaded the GPS data, did data entry for GPS data collected with the Garmin III unit, and kept the survey vehicle and GPS units maintained. The Scientific Aides were supervised and occasionally accompanied by the Research Analyst I (RA I). The RA I also was responsible for differential correction, and maintenance of the GPS data. Towards the end of the season, all the GPS data was brought together in a GIS layer and mapped.

Objective 3

Collect distribution data from project cooperators, and use GIS to map and assess he distribution of yellow starthistle in the Sierra Nevada. Project cooperators sent their YST locations by the end of the Year 2000 growing season. These locations were sent in variety of forms: GPS files, GIS layers, paper maps, and verbal descriptions. All of these formats were brought into MapInfo GIS for analysis. GPS and GIS files were translated into a MapInfo .tab format. For paper maps, USGS 1:100,000 scale digital raster graphics (100K DRGs) were as a background for heads-up digitizing. Verbal descriptions were translated into locations by using a combination of road layers and 100k DRGs. All the data had their attribution standardized into relatively few common elements. Then all the files, including the data from the CDFA survey were seamed together into two GIS layers: one that showed where surveying for YST was done, and one that showed were YST was found. The original data were maintained because they often contained more information than the aggregated GIS layers. Each set of original data was given a code in the database that is also in the aggregated layer, so that the source for each location could be assessed for accuracy with GPS-GIS being the highest, followed by paper maps and then verbal descriptions.

The resulting GIS layers were limited in accuracy and completeness, yet clearly showed useful trends in the distribution of YST and identified some areas as clear priorities for control. Because some of the data were digitized using 100k DRGs, it cannot be used for navigation back to the infestation at a scale greater than 1:100,000. For example, this would allow someone to identify that YST was near Highway 88 between Highway 89 and the Mormon Emigrant Trail, but they wouldn't be able to tell exactly how far from Hwy. 89 the infestation was, nor which side of the road it was on. Another limitation is that there was a tradeoff between amount of ground covered and level of detail in the information. As a result, much of the GPS data did not contain size measurements that would allow for a very accurate assessment of the acreage of YST infestation found in the study area. Another limitation is that much of the data is from road surveys, which means that in some areas the spaces between the roads are an unknown. What the data do show when mapped with DEM data or elevation contours is that except near major highways, YST is not widely distributed much above 4000 feet (See maps B).

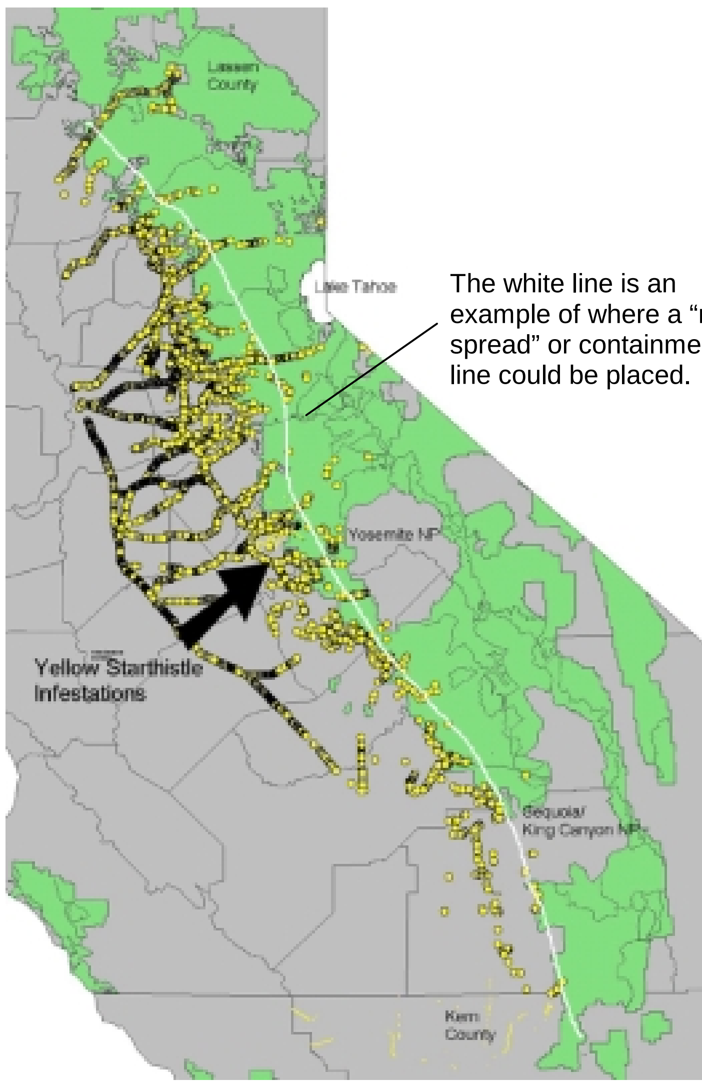
Objective 4

Incorporate information from survey into management plans for yellow starthistle. The Project Coordinator shared the findings of the cooperative mapping study with the Weed Management Areas in the Sierra Nevada during a time when they were putting together proposals for projects to be funded by a State of California appropriation to WMAs (AB1740

Outcome

The cooperative yellow starthistle mapping project did achieve its goal of providing the basis for prioritized control of yellow starthistle in the

Sierra Nevada. With the data that was collected, the control priorities identified were isolated infestations located at over 4000 feet in altitude, and the major highways that had roadside infestation well above that. How that information has been incorporated and used in YST management has yet to be fully evaluated. The project was also a valuable experiment in multi-agency cooperation that showed the strength of Weed Management Areas as organizing units. Finally, it created a rough model for how to organize a multi-agency weed mapping project, that could be used by weed management areas as they begin their weed inventories.



The white line is an example of where a "no spread" or containment line could be placed.

4.9 Case Study: CALTRANS/CDFA Yellow Starthistle Highway Survey, 1999

Between July and October, 1999, seasonal employees of the California Department of Food and Agriculture surveyed highways in the Sierra Nevada for yellow starthistle (YST). The surveyors were using Trimble TDC1 equipment with an antenna mounted to the roof of the vehicle, and would mark points when they saw YST on the roadside. An overview of their survey can be seen on Map 1.

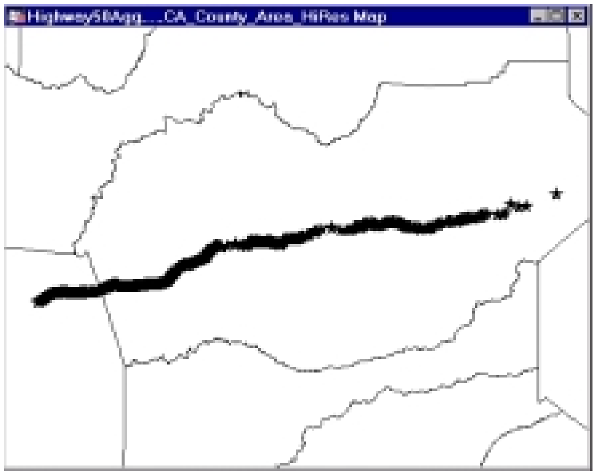
Using the unique Quickmarks feature of the Trimble TDC1, approximate gradations of the level of YST infestation were made by gathering points of three types: low, high, trace (trace being a countable few plants). There would be two people involved in getting the data: a driver and a surveyor, who would hit one of three buttons to mark a YST location: 1. Low, 2. High, 3. Trace. These do not correspond with standard coverage designations (trace<1%, 1%<low<5, 5%<moderate<25%, 25%<high). In this survey, these were approximate quantity designations. At safe driving speeds on highways, it was difficult to assess size and coverage: at 45 mph, you pass .1 of an acre of right of way in approximately 2 seconds. So points marked as High approximated areas of YST > .1 acres; Low < .1 acres of YST, and Trace was a countable few plants.

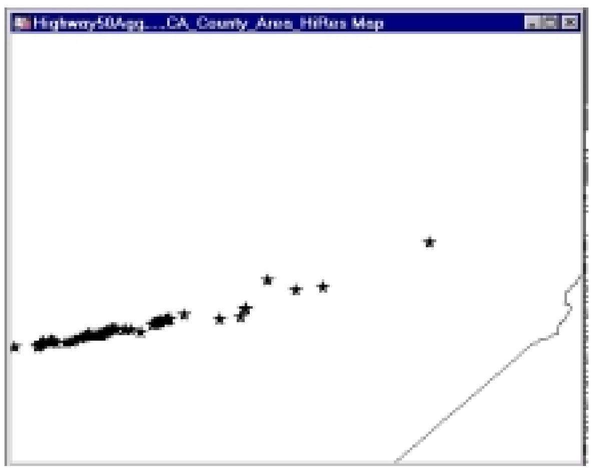
The surveying was generally broken into three legs. The first was a general highway roadside survey. The second was a survey that looked beyond the right of way to see if YST extended past the roadside. The last leg was a re-survey of upper elevations to catch plants that had germinated later in the season.

Once the data had been collected, it was differentially corrected for better accuracy and incorporated into a GIS using MapInfo software. Analysis was performed visually and with the use of GIS software. A distinction was made between lower and higher density locations using a buffering technique. If three points or fewer were separated by more than a kilometer from other points, they were considered low density. These lower density locations (regardless of their infestation level) are considered outlier populations when they are found on the eastern extreme of a road. These infestations are the leading edge of yellow starthistle in the Sierra Nevada, and are crucial to control to stop the eastward spread of YST.

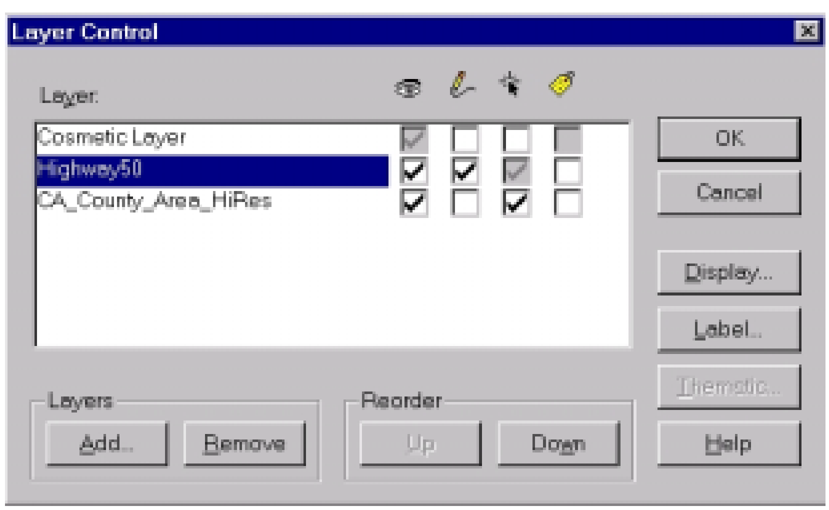
How was this done in MapInfo

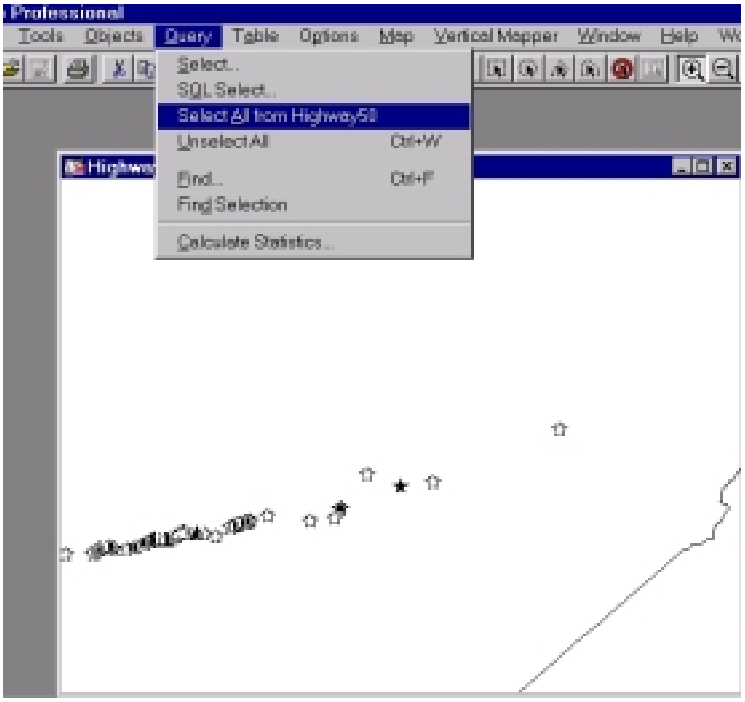
Here are the points from the Highway 50 survey. If you zoom in to the eastern focus of points, you can see that the observations become less frequent.

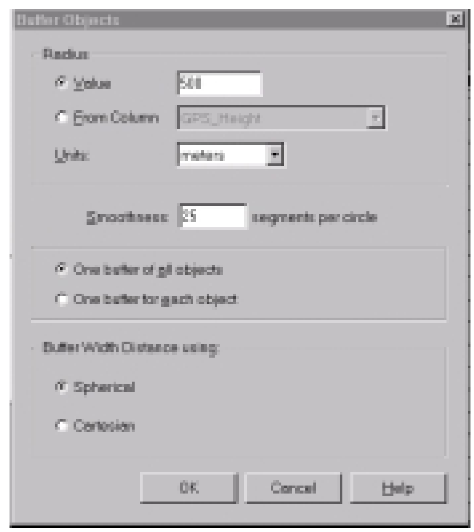




In MapInfo, buffers are added to the layer being buffered, since a single layer can contain points lines and polygons (unlike ArcView). To start the buffering process, the YST layer must be made editable. Then all the points must be selected to make them active when the buffering process takes place.



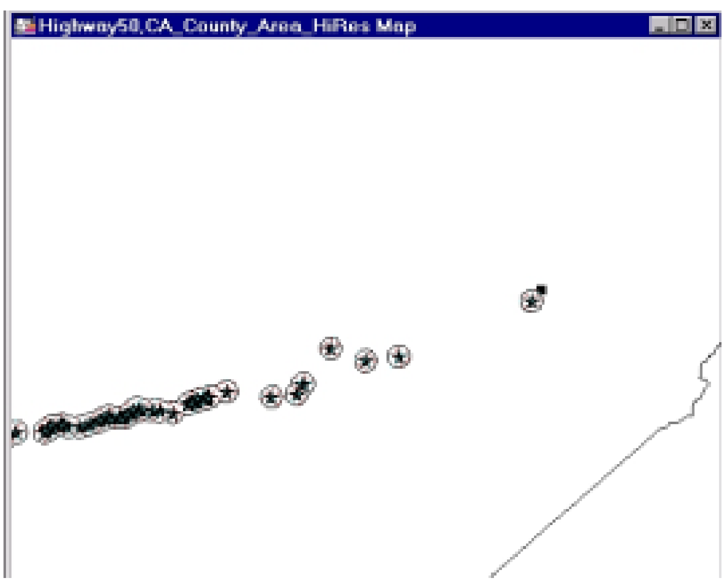




Now you are ready to buffer. First select the buffer to from the objects menu. This brings up the window below. In this scenario, we were trying to make clear where the observations were more than one kilometer apart so a buffer of 500 m was chosen.

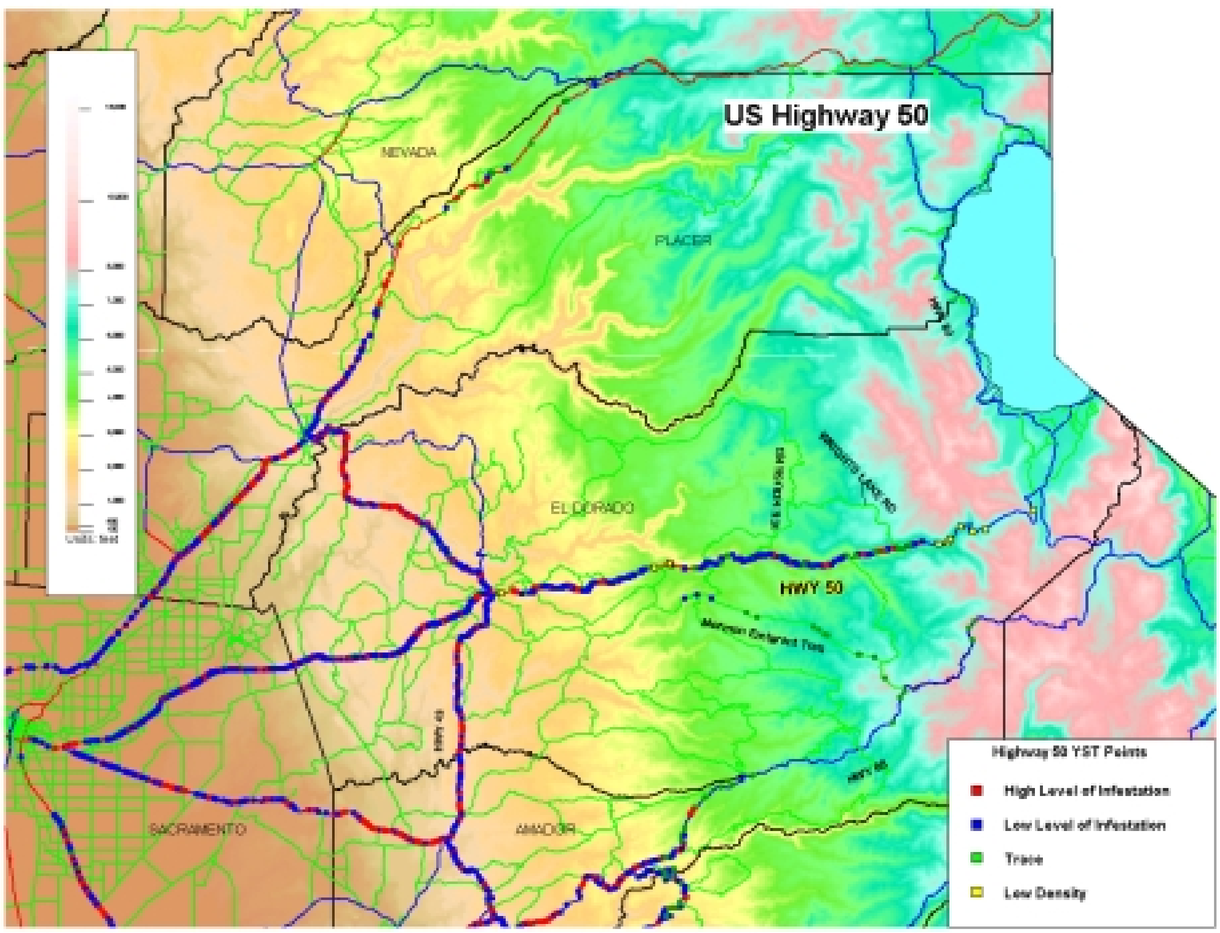
The result is a buffered set of points. Those that met the low density criteria above were visually selected and put into a separate layer.

The resulting map was used to craft recommendations for each highway surveyed.



<u>Example: US Highway 50</u>

(See map below.) This road is infested through most of its length in California. This road should be a priority in YST control, because YST has been seen at altitudes of over 8000 feet on this road, and it is used heavily by cars that will then travel to side roads in the Sierra Nevada. Also it was seen east of Echo Summit. Our survey found no YST on Highway 89 around Lake Tahoe. To make sure that YST does not infest the Tahoe Basin, it is a top priority to eradicate the outlier incidences near the top of Highway 50. CDFA's survey crew pulled many of the plants it found last year near Echo Summit, but those sites should be visited again this season. The density of points drops sharply at Wrights Lake Rd., which may indicate some kind of natural limitation. To be consistent with the 3500 foot leading edge, priority control work should happen on all points east of Sly Park Rd/Mormon Emigrant Trail.



4.10 Case Study: Using Parcel Data to Track a Landowner Cost-share Program

Based on work done through the Kern County Weed Management Area by the Tehachapi Resource Conservation District with the assistance from the Natural Resources Conservation Service.

About the Tehachapi RCD Yellow Starthistle Eradication program

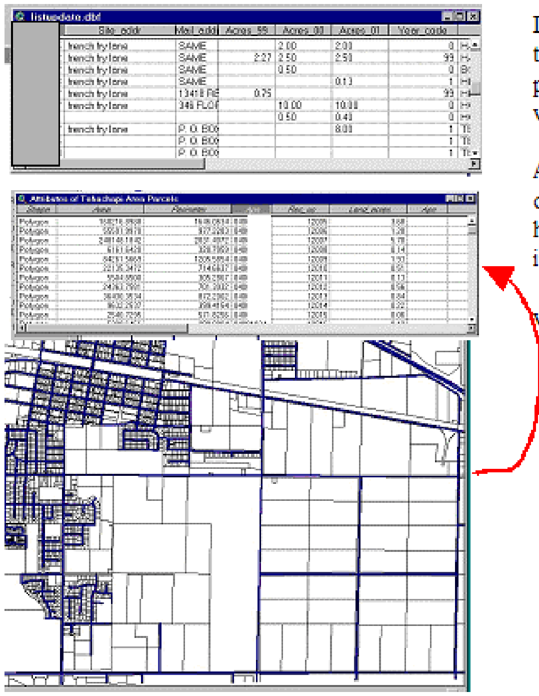
Since 1998 the Tehachapi Resource Conservation District (TRCD) has sponsored a successful Yellow Starthistle (YST) eradication program. This program has been promoted by an intensive campaign of public education through workshops, mailings, signage, frequent news articles and word of mouth since 1995.

In 1999, the first spray season, the program was funded primarily by payments for service by private property owners and, to a lesser degree, local government entities, donations from generous citizens, local businesses, and the TRCD. Education efforts, outreach programs, and computer equipment for mapping were funded by grants from the California Department of Conservation (DOC) and the California Department of Food and Agriculture (CDFA). A Weed Management Handbook, to help others form programs such as the TRCD's, was the major product of this funding. Over 570 acres were sprayed on 104 job sites in this first year of the program.

In the second year, the program was supplemented by funding from the CDFA through the Kern County Ag Commissioner's office and the DOC, enabling the TRCD to use this supplemental funding for spraying and manual removal in major recreation areas and County roadsides. That year, 1174 acres were sprayed on 134 job sites during the 2000 program.

In the third and fourth years, continued supplemental funding by the DOC and CDFA allowed spraying of 1720 acres on 117 job sites for the 2001 program year and about 1822 acres on 167 job sites for 2002 .

The TRCD YST eradication program has resulted in the development of an extensive public relations campaign, a GIS mapping project (assisted by the Natural Resources Conservation Service), adopt-a-park/adopt-a-road programs, follow up evaluation studies, and continual grant opportunities.

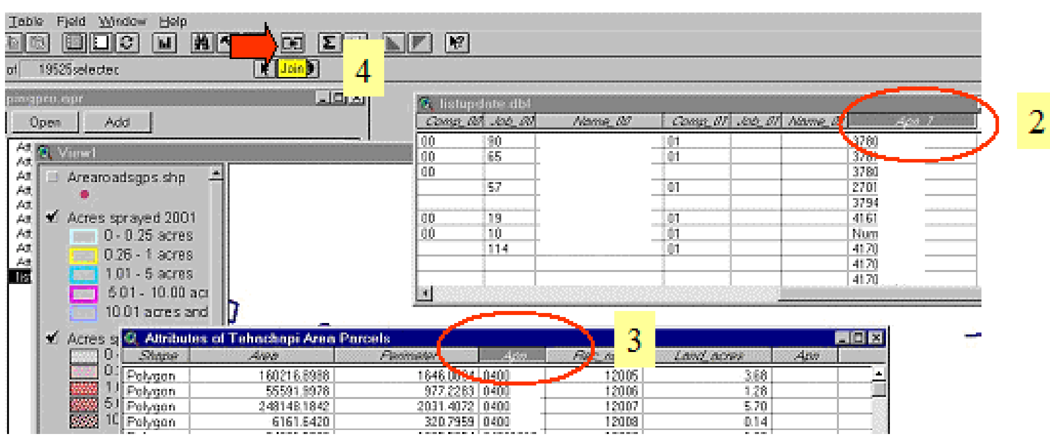


In this project, the county has made their parcel GIS data available. The parcels each have an APN # associated with them.

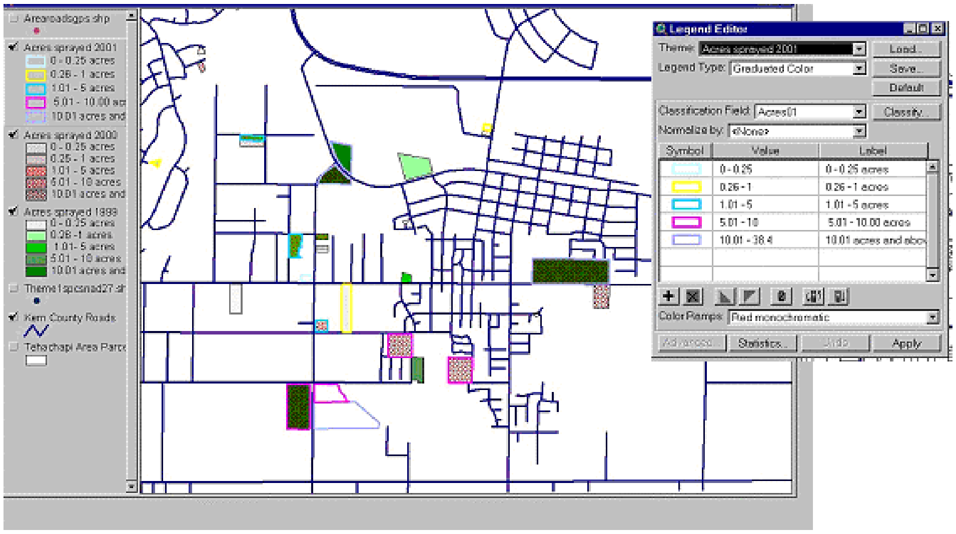
A table was created to track work on the costshare program. Each parcel treated had a record that stored owner contact info and the number of acres of YST treated each year. The APN # was also stored with each record.

The parcels are shapefile with both a spatial component (polygons) and attributes.

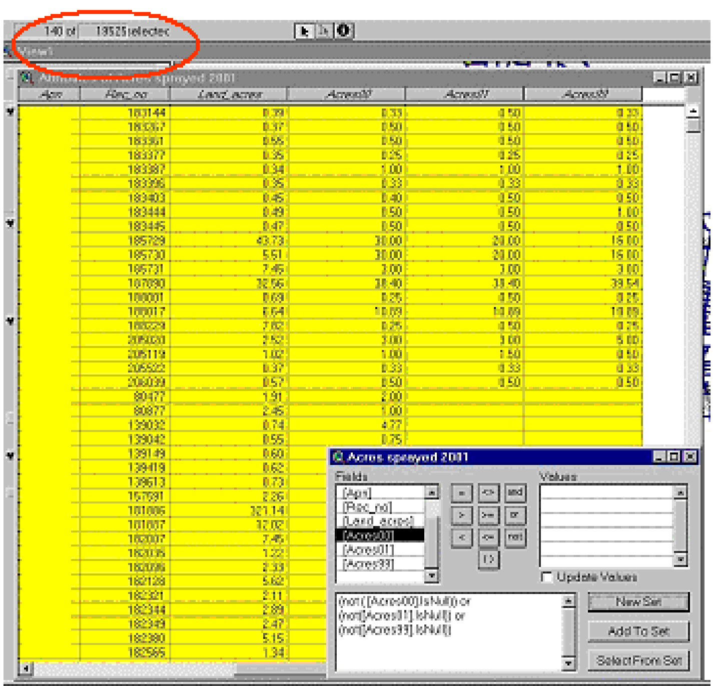
The treatment tracking table (listupdate.dbf) is not spatial



To make the treatments mappable, they must be joined to the parcels. To do this:
1 Both tables are opened.
2 The treatments table (the source table) is made active and the APN # was highlighted.
3 The parcels table (destination table) is made active and the APN # was highlighted.
4 The Join button is clicked. The parcels of interest can now be saved as a new shapefile to be used in this and other projects, or joined table can now be mapped, and the join will dynamically maintain the link between the treatment table and the parcels.

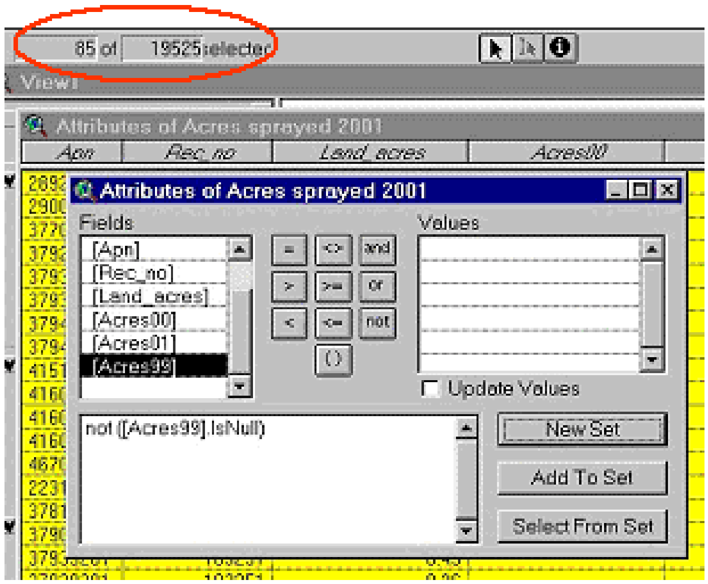


By adding the same shapefile 3 times to a view and then using the legend editor to create a color ramp for each year's treated acreage, it is possible to produce a map showing which acres were treated in which years, and how much was treated

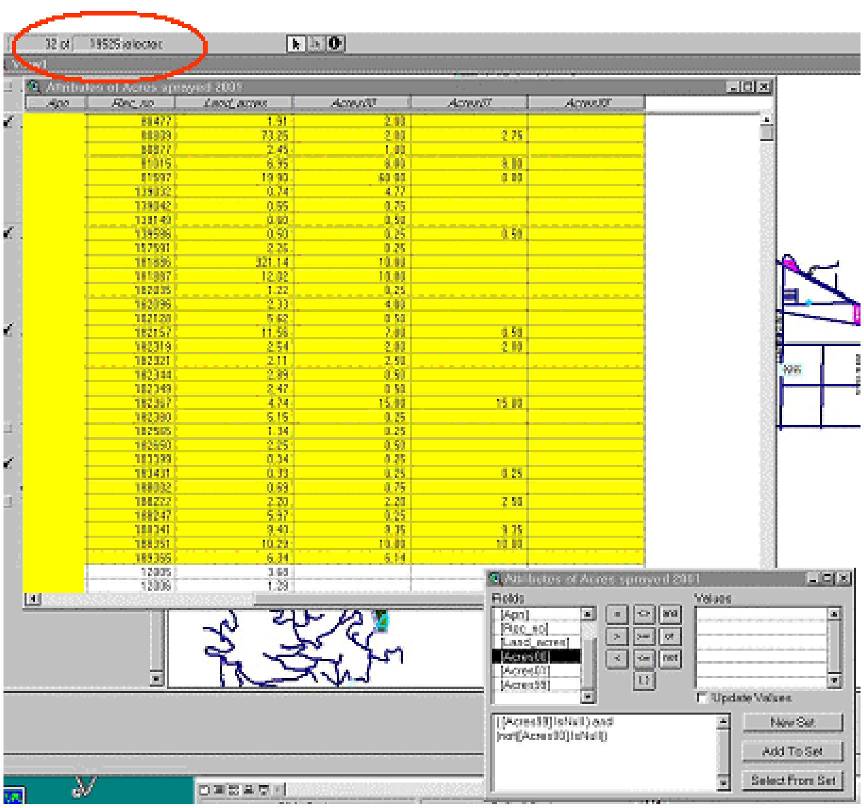


A lot more can be done with this information. Some basic queries can answer questions about the program.

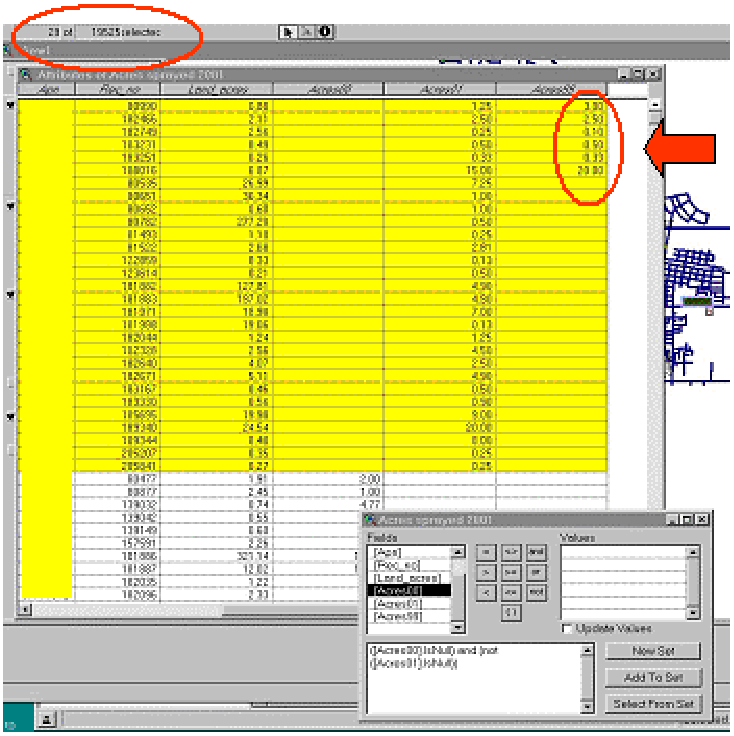
This query shows how many parcels (that were tracked with apn #s) were treated in the program.



This one shows how many of those parcels were treated in the first year.



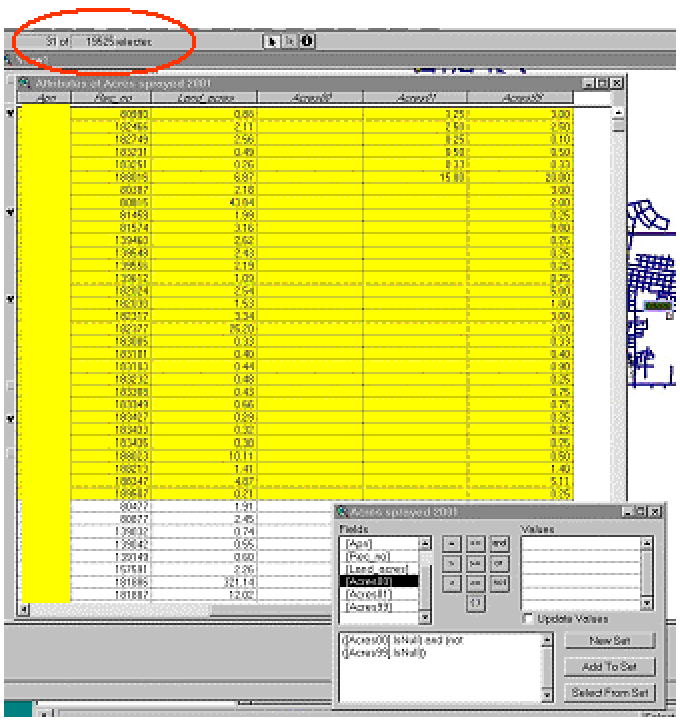
This one shows how many started treatment in the second year.



-6 that were treated in 99

This one shows parcels treated the 3rd year that were not treated the 2nd year.

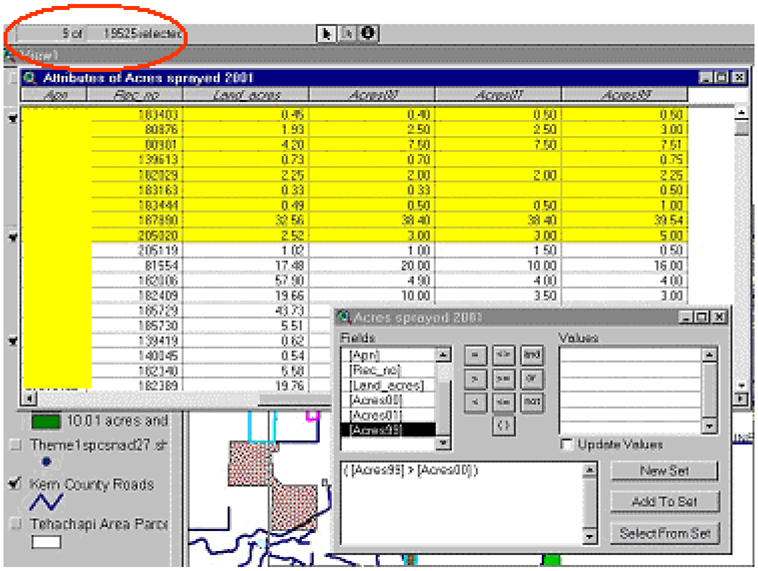
So of the 140 treated parcels
85 came on in year 1
32 came on in year 2
23 came on in year 3



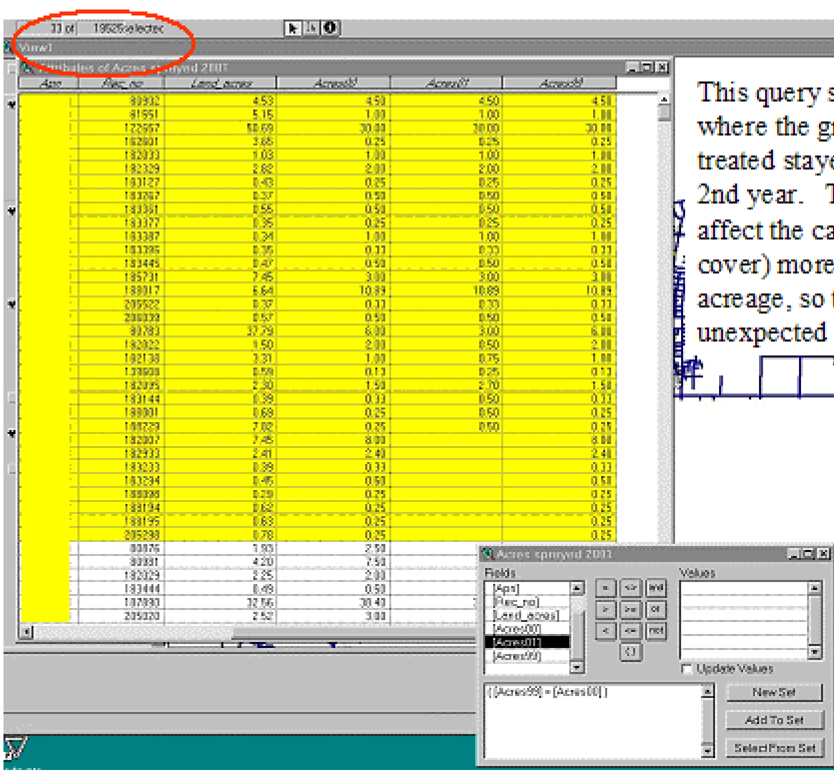
This query shows parcels that were treated in the first year, but not in the second.

If the owners were required to report if they had no treatable acreage the following year, then you would be able to identify those by putting zeros in those records, and separate those parcels from parcels that the owners simply chose not to treat that year.

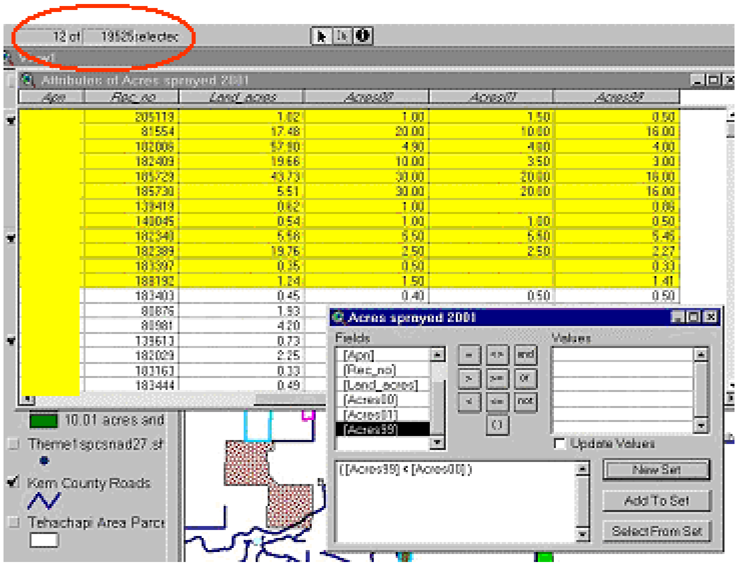
That is not the case here.



This query shows the parcels where the gross acreage treated shrank in the 2nd year.



This query shows the parcels where the gross acreage treated stayed the same in the 2nd year. Treatments often affect the canopy cover (% cover) more than the gross acreage, so this is not an unexpected result.

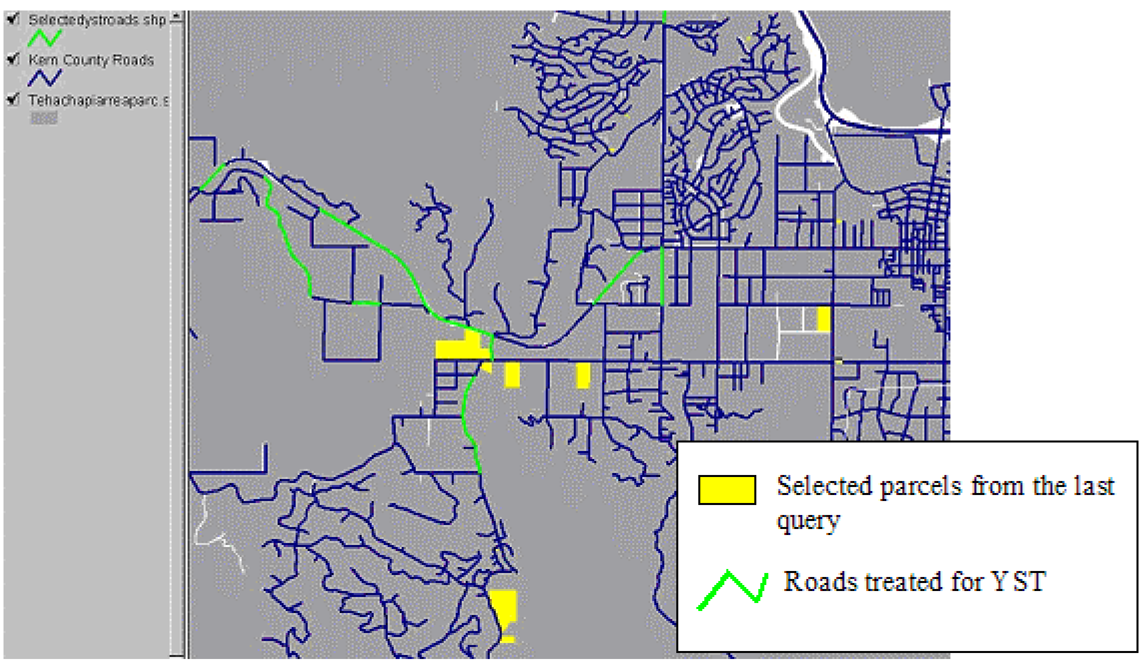


This query shows the parcels where the gross acreage treated increased in the 2nd year.

This shows the importance of having some measurement, either net acres or % cover that can track changes in actual coverage.

To get this data, it may be necessary to require the landowners provide documentation as a condition of participation

In summary, in year 2
of the owners that were part of the 1st year
31 parcels did not treat
09 parcels saw the gross acres shrink
33 parcels kept the same gross acres
12 parcels saw the gross acres increase



All of the analysis to this point could have been done with a database. But once you get to the point where you have identified issues for investigation, GIS becomes very handy. Are all the parcels that showed an increase in gross YST acreage between year 2 and 1 clumped? Do they always correspond with roads that needed treatment? This map could also be printed and field checked for other diagnoses.

4.11 California State Parks' Mapping and Inventory Protocol

INVENTORY & MONITORING PROTOCOLS – INVASIVE ALIEN PLANTS ONE TIME USE OF ANY OF THESE LEVELS IS INVENTORY, MONITORING REQUIRES MULTI-TIME USE.			
Survey Level	QUESTIONS	METHODS	PRODUCTS
Preliminary (office oriented)	• What invasive alien plant taxa are known to occur in the unit? • What plant communities at the unit are known to be invaded by invasive alien plants?	• Conduct literature and database searches (References #1, 4) • Consult with knowledgeable persons and agencies (Reference #4) • Review any existing documents for the site (Reference #4) • Visit herbaria	• A list of invasive alien plant taxa that have been documented in the unit from past site visits or studies.
Reconnaissance (field oriented)	• What invasive alien plant occurrences exist at the unit?	• Walk-through, drive-by, fly-over, and look at photos of the site • Create a list of invasive plant taxa observed during site visits (References #5, 6, 7, 8, 9, 10 for help with identification of some invasive taxa and eradication techniques). • Have experts verify taxa in question. • Take generalized photos (Reference #3)	• Products of the Preliminary Level plus: • A list of invasive alien plant taxa observed at the site during site visits • Completed annual inspection & questionnaire • Rapid assessment of invasive alien plant occurrences
Baseline (field oriented)	• Where are the invasive alien plant occurrences located in the unit? • Is the invasive alien plant occurrence new or absent compared to previous years? • Is there an apparent change in the taxon or its habitat at the site of the occurrence compared to previous years?	• Methods outlined in the Preliminary Level plus: • Visit the unit with aerial photographs and topographic maps and systematically search the suitable habitat on foot during the appropriate blooming period (for taxa that must be blooming for proper identification) (Reference #1). • Establish photo stations, make general observations of the site, and note associated taxa. (Reference #3) • Use the Sawyer-Keeler-Wolf plant communities classification system to identify plant at the unit where invasive alien plant taxa are observed. (Reference #2) • Use a Global Positioning System (GPS) unit to create a map of plant taxa locations as points in GIS. Map and number each occurrence. • Outline the surveyed area by hand onto a topographic map. • Use the ArcView or ArcInfo software to generate maps. • Compare maps year to year to ascertain change (Monitoring).	• A comprehensive list of the invasive alien plant taxa occurrences at the unit and the associated taxa. • A comprehensive list of the plant communities at the unit where invasive alien plant taxa occurrences exist. • GIS map with invasive alien plant taxa locations at the unit mapped as points or polygons. • A map of the surveyed area. • Photos of taxa and/or populations.
Baseline (field oriented)	• What is the areal extent of the invasive alien plant occurrences in the unit? • What is the change in areal extent of the invasive alien plant occurrences?	• Methods outlined in the Preliminary Level plus: • Map the stand or population perimeters as polygons using a GPS unit (some stands of larger taxa may be mapped using digital imagery in ArcView or ArcInfo). • Map entire area surveyed on a topographic map or GIS map, or by using digital imagery in ArcView or ArcInfo. • Create a GIS map using the ArcView or ArcInfo software. • Repeat the above periodically and compare results to previous years (Monitoring).	• Products of the Preliminary Level plus: • GIS map of invasive alien plant occurrences and the entire area surveyed. • Calculation of acreage of each occurrence or of all occurrences of a particular taxon using GIS.

INVENTORY & MONITORING PROTOCOLS – INVASIVE ALIEN PLANTS ONE TIME USE OF ANY OF THESE LEVELS IS INVENTORY, MONITORING REQUIRES MULTI-TIME USE.			
Survey Level	**QUESTIONS**	**METHODS**	**PRODUCTS**
Comprehensive (field oriented)	• How many individuals of the invasive alien taxon are present in each occurrence? • What is the phenology of the taxon, and condition of individuals in the occurrence? • What is the species composition or richness, dominant taxa, condition of habitat, percent cover by species, relative abundance, height classes, distribution of the taxa, reproduction/recruitment rate, timing of phenological changes, frequency, density of the taxon within the occurrence? • What are the changes in the above-mentioned attributes?	• Methods outlined in the Preliminary Level plus: • Establish transects and/or quadrats to collect data on numbers, phenology, disease, predation, mortality, etc., in all or a subset of the occurrences at the unit (Reference #4). • Establish transects and/or quadrats to collect data on %cover, relative abundance, recruitment, height classes, mortality or disease (Reference #4). • Use appropriate statistics to analyze data (Reference #4). • Map locations of transects and quadrats using GPS unit. • Create a GIS map using the ArcView or ArcInfo software. • Repeat the above periodically and compare results to previous years (Monitoring).	• Products of the Preliminary Level plus: • Data on abundance, frequency, density, richness, cover, condition of occurrence and habitat, mortality, etc. • Detect changes and trends in the above. • Map of transect and quadrat locations.
Intensive (field & laboratory-oriented)	• Questions related to demographics, genetics, energy/nutrient cycling, pollination biology, etc. • How are the population demographics or other attributes changing?	• Methods will be dependent upon the nature of the question and the taxon. Standard protocols, when available and applicable, should be employed. • Repeat the above periodically and compare results to previous years (Monitoring).	• Detailed and intensive studies and reports on an attribute of interest with regard to an invasive alien plant taxon or occurrence specifically. • Detect changes and trends.

References:

1) Barry J. 2000. Handbook for Vegetation Inventory Monitoring and Assessment of the California State Park System. (unpublished report). Obtain from the California State Parks Headquarters IMAP team, Sacramento
2) Sawyer, John O. and Todd Keeler-Wolf. 1995. A Manual of California Vegetation. Published by the California Native Plant Society. 471pp. The ISBN (softcover) is 0-943460-26-2. The ISBN (hardcover) is 0-943460-25-5. Obtain a copy by ordering from the California Native Plant Society, 1722 J Street, Suite 17, Sacramento, CA 95814. Phone 916-447-2677. Or order on the California Native Plant Society Bookstore website at: www.CNPS.org/bookstore/sellers.htm
3) Magil, A.W. 1989. Monitoring Environmental Change with Color Slides. General Technical Report PSW-117. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture. 55pp. To obtain contact: Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, CA 94701 or online at the USDA Forest Service Pacific Southwest Research Station Publications website at: www.psw.fs.fed.us/techpub.html
4) Elzinga, C.L., D.W. Salzer, & J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1. 477pp. Obtain a copy from: Bureau of Land Management, National Business Center, BC-650B, P.O. Box 25047, Denver, CO 80225-0047
5) U.S. Department of Agriculture Exotic & Invasive Weeds Research Unit website at: http://wric.ucdavis.edu/exotic/exotic.htm
6) California Exotic Pest Plant Council (CalEPPC) website: www.caleppc.org
7) Calweed Database website at: http://endeavor.des.ucdavis.edu/weeds
8) California Department of Food and Agriculture, Encycloweedia website at: http://pi.cdfa.ca.gov/weedinfo/
9) Robbins, W.W., Margaret K. Bellue, and Walter S. Ball. 1970. Weeds of California. 547 pp. The book can be purchased by contacting Documents and Publications, P.O. Box 20191, Sacramento, CA 95820
10) Bossard, Carla C., J.M. Randall, and Marc C. Hoshovsky, eds. 2000. Invasive Plants of California's Wildlands. 360 pp. The ISBN is 0-520-22547-3. The book may be purchased at various bookstores or through Amazon.com